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THE VEGETATION REGIONS OF THE PRAIRIE PROVINCE.

ROSCOE POUND and FREDERIC E. CLEMENTS.

(WITH PLATE XXI)

THE vegetative covering of the North American continent falls naturally into two great areas, forest and plain. At first thought it would seem that these were primary phytogeographical divisions, but a comparison with the vegetative covering of other continents proves the contrary. Considered as a phytogeographical feature, the North American forested area is an entity; from a floristic or formational standpoint, it may be analyzed into several distinct portions of widely separated relationship. The ground-tone of the great bulk of the North American forests is that of the forests of British North America, which are closely related to those of middle-north Europe and Siberia, constituting with them the northern realm of Drude and the sub-arctic region of Engler. Three great belts extend southward from this northern mass, each undergoing profound changes in type, and becoming differentiated into well-characterized regions. The floristic separation of these regions from the northern forest-region is so great that the relationship is always much less close than that existing between the floral covering of British America and that of northern Eurasia, and in one or two cases it practically disappears. The forests of Mexico and Central America are tropical, or subtropical, and are both

floristically and formationally distinct from the northern forests. So different are certain portions of the plains with respect to vegetative covering that they may be regarded as scarcely more than topographically similar. If North America were to be considered alone, a primary division of the vegetative covering into forest and plain would be useful in certain respects. But these areas are merely the North American representatives of certain zones or realms among those into which the vegetation of the entire earth is divided. In consequence they are not to be distinguished as phytogeographical divisions at all, but as aggregates of divisions, which are characterized by a common type of vegetation-form, or by a group of such types.

Grisebach, having in mind apparently only the gross features of the continental floral covering, distinguished but four divisions, forest domain, prairie domain, Californian littoral domain, and Mexican domain. In the prairie domain he includes not only the prairies proper and the great plains, but the great basin, and the high plateaux of Arizona and New Mexico as well, styling them eastern, northern, and southern prairies respectively. Grisebach practically disregards the true, or eastern prairies, characterizing only the northern and southern ones, which are by no means prairies in a phytogeographical sense, and scarcely more in a physiographical one. As a result of more careful analytical study of the floristic features of the continent, Engler has separated the floral covering into seven provinces: (1) North American lake province, (2) Appalachian province, (3) Prairie province, (4) Californian coast province, (5) Oregon province, (6) Rocky mountain province, (7) Colorado province, the last comprising the vast unforested region between the Rocky mountains and the Sierra Nevada. In 1887, in the *Atlas der Pflanzenverbreitung*, disregarding division into provinces, Drude outlines a number of vegetation regions upon the floral map of North America, which correspond to the regions proposed in his *Handbuch der Pflanzengeographie*. These are fourteen in number: (1) Glacial forest and thicket region of Alaska, (2) Canadian forest region, (3) forest region of the North

American lake country, (4) Columbian littoral forest region, (5) forest and alpine region of the northern Rocky mountains, (6) northern forest-prairie region, (7) Missouri prairie region, (8) steppe and salt-waste region of the Rocky mountains, (9) Californian lowland, subalpine and alpine region, (10) deciduous forest region of the Mississippi basin, (11) evergreen region of the South Atlantic states, (12) steppe and desert region of Arizona, (13) chaparral region of Texas and northern Mexico, (14) North Mexican subalpine and alpine region. Many of these regions are well defined, while others manifest too great reliance upon inaccurate data. This is especially evident in the case of the Missouri prairie region, which is erroneous both as to boundary and as to characterization. Drude makes the eastern boundary of this region follow the west bank of the Mississippi to the confluence of the Ohio, where it bends to the east to include the greater portion of Illinois, then turns westward along the southern border of Wisconsin to the Minnesota valley, whence, passing into the northern forest-prairie region, it runs northwest to Beaver river in Saskatchewan, and then southwest to the head waters of the Saskatchewan in the foothills of the Rocky mountains. Taking the western border of the 20 per cent. wooded area as the line of demarcation between the forests of the Alleghany province and the prairie province, the eastern third of Texas, most of the Indian territory, nearly the whole of Missouri, and the southern portion of Iowa, belong to the forested province. Even if a much higher per cent. of woodland be thought necessary to characterize an area as forested, the dense woods of Louisiana, Arkansas and Missouri are indubitable evidence that these states are an integral part of the Alleghany province. To the north of the prairies of the Missouri, Drude distinguishes the prairies and plains of Manitoba, Saskatchewan, Alberta, and Athabasca as the northern forest-prairie region. As will be demonstrated later, these are essentially identical with Missouri prairies, and are in no wise to be distinguished from them. Along the Rocky mountains, Drude refers a broad strip of plain and foothill, comprising a

large portion of Montana, western Dakota, eastern Wyoming and Colorado and western Nebraska, to a transition-region, connecting the prairies proper with the elevated plains of the Great Basin country. The eastern foothills of New Mexico are included by him in the steppe and desert region of Arizona. Topographically and phytogeographically, the foothills along the eastern border of the Rocky mountains are an intrinsic portion of the great plains, and, as such, are to be included in the prairie province. On the south, while extending the domain of the prairies to the Gulf of Mexico, Drude distinguishes the prairies beyond the Canadian river as southern prairies. It is doubtful whether he would have us consider this a region; at any rate he does not expressly term it such, as is the case with the Saskatchewan prairies. However, a glance at the flora of the geographical extremes of the prairie province will demonstrate that neither the northern nor the southern prairies are regionally distinct from the central mass, but that they merely manifest such "shading-out" as is always present toward the confines of large vegetation-regions.

Turf-builders are the most important vegetation-form for the characterization of the prairies, and in determining the floral contrast between regions, and the degree of such contrast, they are first to be considered. Of the thirty-three species of grasses which comprise the facies and the principal species of the prairie province formations, the prairies of Nebraska, Kansas, and the Dakotas possess the entire number; those of Saskatchewan, Manitoba, etc., possess thirty species; and those of the Red river country, twenty-nine species. From this it is seen that the fundament of the floral covering of the prairie province is essentially homogeneous from the northern extreme to the southern extreme. Of the thirty-six species which constitute the formational facies of the prairies, the central prairies (central in a purely geographical sense) possess the full number; the southern prairies thirty-one species; and the northern thirty-two species. Of one hundred and forty species most important with respect to frequence, abundance, or characteristic, eighty-three are

common to the entire province, while one hundred and twenty-nine are found throughout the central and southern portions, and ninety-one throughout the central and northern portions. The vegetation-center of the prairies is found in Nebraska, Iowa, Kansas, and the Dakotas. From this center the typical plains flora slowly shades out toward both north and south; naturally enough over a country so little diversified with about equal rapidity. The effect of higher altitudes and greater distance from the vegetation-center accounts for the greater ultimate reduction in number of species to the northward. The fact that species of distinctly northern range are found only in one extreme of the prairie province, or those of southern origin only in the other, is of trifling importance. All vegetation regions, and none more readily than a plains region, where dissemination is so easily effected, borrow floral elements from adjacent regions, and it is only when this invasion has resulted to a pronounced degree that the original floral covering changes aspect. As has been stated above, the facies and principal species of the province are essentially the same throughout, and the comparatively small number of strictly southern, or northern species are of purely secondary importance in the consideration of the floral covering.

In the characterization of the Missouri prairie region, Drude cites *Bouteloua oligostachya* and *Bulbilis dactyloides* as the most common prairie grasses. Both of these grasses, in fact, are equaled in abundance and in importance by several species, such as *Andropogon scoparius*, *Aristida purpurea*, *Stipa comata*, *Agropyron pseudorepens*, and *Koeleria cristata*, all of which are of the widest distribution. Bulbilis, on the other hand, is entirely lacking over the vast prairies of the Saskatchewan. It may be remarked in passing that the supposed disappearance of buffalo-grass, *Bulbilis dactyloides*, connected more or less poetically with the vanishing herds of bison, is a popular myth. The buffalo-grass at the present time undoubtedly covers as large an area geographically as it ever occupied within the memory of man, and is quite as abundant over this area, except for the diminution

due to artificial factors, such as the "breaking" and the cultivation of the prairies. The mistaken idea concerning the distribution of Bulbilis has arisen from the statements of trappers, scouts, and frontiersmen, who invariably confused, and still confuse, Bulbilis and Bouteloua, thus assigning to the former not only its proper geographical area and abundance, but, in addition, that of *Bouteloua oligostachya* and *B. hirsuta*. Another popular fallacy is that the blue stems, *Andropogon provincialis* and *A. scoparius*, are slowly advancing westward across the plains, an advance often connected with the supposed disappearance of Bulbilis. In fact, both species are as truly endemic in the sand hills and foothills as they are on the eastern prairies. In addition to Bouteloua and Bulbilis, Drude enumerates *Agropyron pseudorepens*, *Oryzopsis cuspidata*, *Stipa viridula*, *S. setigera*, *Andropogon Virginicus* and *A. glomeratus* as characteristic species. The last two are not found within the prairie province proper, *Stipa setigera* is common only south of the Arkansas, and *S. viridula* is abundant only along the foothills, and on the prairies of the extreme north.

That it is impossible for a phytogeographer to treat accurately the floristic and the distribution of a distant flora which he has not seen, is well exemplified in Drude's *Florenkarte von Amerika*. *Quercus rubra*, which on his map has a western distribution running from the southwest corner of Nebraska to the mouth of the L'eau-qui-court in the northeast, occurs in the state only in the southeast corner in the red oak-hickory formation of the Missouri woodlands. On the other hand, the western limit of *Quercus macrocarpa* does not run north and south through the sand hills, but bends to the westward, passing beyond the Nebraskan border into Wyoming and the Black hills of South Dakota. *Juglans cinerea* and *J. nigra*, which, according to Drude, scarcely cross the Mississippi, likewise occur in Nebraska. The former is found in the southeast corner of the state; the latter, as a facies of the bur oak-elm-walnut formation, extends halfway across the state along the L'eau-qui-court and the Republican.

The main features of the regional limitation and character-

ization, and the formations, briefly discussed in this article, are based upon a treatise entitled *The Phytogeography of Nebraska*, recently published by the authors of the present paper. The data have been extended, however, to cover the entire prairie province, while in the work referred to only the territory embraced in the political limits of Nebraska is considered.

Considering Nebraska alone, the floral covering of the state falls into four vegetation-regions: I. Wooded bluff and meadowland region; II. Prairie region; III. Sand hill region; IV. Foothill region. Region I consists of a narrow strip along the Missouri. It is an arm of the extreme western edge of the Alleghany forests, which projects northward into the prairie province as far as the Great Bend of the Missouri. Although almost surrounded by prairies, it is in no sense a portion of the prairie province. It is a portion of the Mississippi-basin region. On the central plains, especially those of Nebraska and Kansas, regions II, III, and IV are well-differentiated, both topographically and phytogeographically. As physiographic features, the prairies proper (including those of Iowa and Illinois), extending from the forest to the 98th meridian, are easily distinguished from the sand hills, and the latter, finding a general western boundary between 102–103° W., are very distinct from the foothills. To the south, in the Indian territory, the prairies proper are crowded out by the sandy plains, and the prairie region disappears, leaving regions III and IV. On the Saskatchewan plains, the forests close in on the east, and the sandy plains drop out, resulting in a similar reduction, though here it is region III which disappears. Isolated areas of sandy coteau or coulée occur more or less frequently, however, so that most of the sand hill xerophytes are represented. The more typical species, such as are characteristic of sandy fastnesses, like the Loup district in Nebraska, are necessarily lacking. As a consequence of the stronger development of region II to the northward and of region III to the southward, the division of the prairie province gives to it a peculiar dovetailed appearance. The prairie region tapers gradually to the south, finally dis-

appearing in the Indian territory. The sand hill region likewise narrows toward the north, but much more rapidly, vanishing in the Dakotas, and attaining only occasional expression to the northward. The submontane region IV skirts the base of the Rocky mountains from Athabasca to New Mexico.

It is unnecessary to speak at length of the physiography of the three regions. The most noticeable topographic feature that gives character to the floral covering is soil composition. This, with altitude and precipitation, comprises the great factors which have brought about the differentiation of the prairies into three regions. Thus, while the prairies proper differ in the character of their gently undulating surface from the ridged and broken sand hills, and from the elevated tablelands of the foothills with their precipitous cañons, the important fact for the floral covering is that the soil of the prairie is a close loam instead of a loose sand, as in the sand hills, or an argillaceous marl, as in the foothills. Secondary to this only, is the decrease in precipitation, and the increase in altitude from the eastern boundary of the province to the western. Of equal if not greater importance for the flora is the question of environment, *i. e.*, the derivation of the floral elements. The vegetative covering of the foothills is derived primarily from the mountains, with the exception of the fundament which it has in common with the other regions. That of the prairies proper has come in part from the wooded region to the east. The flora of regions II and IV is a derived one, and the regions may be termed open. The sand hills, while they have drawn somewhat from II and IV, are at no point in direct contact with the flora of another province. The flora is to a large degree endemic, and the region is more or less closed.

The characteristic formations of the prairie province are xerophytic, occasionally poophytic. These are meadow, prairie, sand hill and foothill formations. Not infrequently, certain ruderal formations of xerophytic character acquire great prominence, as in the Niobrara district of the sand hill region. Meadow formations are never xerophytic, but always mesophytic

or poophytic. Naturally, they occur throughout the three regions. The central portion of the prairie province possesses but a single type of meadow formation, the long-stemmed grass meadow, in which the facies are *Elymus Canadensis*, *Stipa spartea*, *Agropyron pseudorepens*, *Panicum virgatum*, *Andropogon provincialis*, and *Spartina cynosuroides*. This meadow formation exhibits a number of aspects in different stations. It is frequently reduced to a single facies. In sloughs and low meadows, this facies is *Spartina cynosuroides;* over certain upland meadows, it is *Stipa spartea*. The most common association of facies is that of *Elymus Canadensis*, *Panicum virgatum*, *Agropyron pseudorepens*, and *Andropogon provincialis*, which occur in meadows throughout, especially in the sand hills. The prairie and sand hill formations attain their fullest expression in their respective regions, but are not necessarily confined to them. Both prairie formations occur in the dry valleys of the sand hill region, and the bunch grass formation of region III is found upon the sub-sand hills of the prairie region. Foothill formations, on the contrary, are restricted to their proper region.

Prairie formations are of two types, the prairie grass, and the buffalo grass formation. The former covers the eastern portion of the prairie region, Illinois, Iowa, eastern Dakota, Nebraska and Kansas. The facies are species of *Sporobolus*, *Koeleria cristata*, *Eatonia obtusata*, and *Panicum Scribnerianum*. Frequently the facies of the meadow formations enumerated above assume sufficient abundance on the prairies to warrant ranking them as facies of the prairie grass formation. Like most formations of regions possessing a long growing period, the prairie grass formation manifests two different temporal aspects, a vernal and an estival-serotinal aspect. During the former, the ground-tone of the formation is due to the uniform green of its facies, which is slightly variegated by *Draba Caroliniana*, *Antennaria campestris*, *Anemone Caroliniana*, *Baptisia bracteata*, *Astragalus crassicarpus*, etc. The extremes of the estival-serotinal aspect might well be separated, if the one group did not pass so gradually and completely into the other. Two

groups, the one earlier, the other somewhat later, may be distinguished, however. The former comprises *Amorpha canescens*, *Kuhnistera candida*, *Psoralea floribunda*, *Solidago rupestris*, *S. rigida*, *Verbena stricta*, *V. hastata*, etc.; the latter, *Laciniaria squarrosa intermedia*, *L. scariosa*, *L. punctata*, *Vernonia gigantea*, *Aster sericeus*, and the aianthous bloomer, *Aster multiflorus*.

The buffalo grass formation is characterized by two types, the Bulbilis type and the Bouteloua type. The geographical area of the former is large, but greatly interrupted, and, while the facies manifests great abundance, its frequence is not comparable to that of *Bouteloua oligostachya* or *Andropogon scoparius*. The dense mats of buffalo grass render this formation fairly exclusive, except where it is interrupted. The number of secondary species is small. They are for the most part reduced facies of adjacent formations, *Aristida purpurea*, *Agropyron pseudorepens*, *Distichlis spicata stricta*, *Koeleria cristata*, and the ubiquitous Boutelouas. The ground-tone of the formation is communicated to it by the buffalo grass. *Asclepias pumila* and *Verbena bipinnatifida*, though characteristic of this formation, have little effect upon it. *Amorpha canescens*, *Kuhnistera candida*, and *Solidago Missouriensis* are common in this as in the prairie grass formation. The fullest development of this formation is found in the Dakotas, and eastern Montana, from which it extends southward through Nebraska and Kansas. The Bulbilis type prevails, for the most part upon argillaceous table lands. On the other hand, the Bouteloua type is found over sandy stretches, and hence is characteristic of the transition area between the prairies and the sand hills.[1]

The sand hill formations are three, the bunch grass, the blow out and the sand draw formations. The first covers by far the larger portion of the sand hills, and sandy plains of region III; the other two are restricted to the topographic features from

[1] The facies is *Boutelona oligostachya*, replaced on the bottoms of long cañons by *B. curtipendula*. The former is scarcely less exclusive than Bulbilis in typical situations, where it composes from 92 to 98 per cent. of the vegetation. In the transition area between regions II and III it admits a number of secondary species, such as *Solidago mollis*, *Lygodesmia juncea*, *Plantago Purshii*, etc.

which they are named. The bunch grass formation exhibits two types, the blue-stem formation, which reaches its chief development in the sand hills proper, and the beard grass formation, which is characteristic of sandy plains and sub-sand hills. Both are open formations of a pronounced type; in the first, the individuals are 1–3 meters apart. Owing to the xerophytic nature of these formations, not only are the grasses bunched, but nearly all principal and secondary species assume the tufted habit. An additional characteristic directly traceable to the same conditions is the exceedingly long tap root developed by most sand hill inhabitants. The facies of the blue-stem formation are *Andropogon scoparius*, *Stipa comata*, *Calamovilfa longifolia*, and *Andropogon Hallii*. The first is the most characteristic on account of the striking bunches which it forms. *Stipa comata* is especially frequent and abundant. In certain situations, both are to a considerable extent replaced by *Calamovilfa longifolia*, *Andropogon Hallii*, and even at times *A. provincialis*, all of which except the last occur throughout the formation. The secondary species are *Eragrostis trichodes*, *Oryzopsis cuspidata*, *Muhlenbergia pungens*, *Bouteloua hirsuta*, *B. oligostachya*, *Sporobolus cryptandrus*, and *Cyperus Schweinitzii*. Important modifications of this formation are imparted to it by the sand-cherry, *Prunus Besseyi*, prairie rose, *Rosa Arkansana*, *Amorpha canescens*, *Ceanothus ovatus* and *Yucca glauca*. The number of secondary species is so great that only the most conspicuous can be mentioned: such are *Cycloloma atriplicifolium*, *Froelichia Floridana*, *Eriogonum annuum*, *Chrysopsis villosa*, *Eriocarpum spinulosum*, *Opuntia humifusa*, *Cactus viviparus*, *Psoralea lanceolata*, etc.

The facies of the beardgrass formation are *Aristida purpurea*, *A. basiramea*, and *Sporobolus cuspidatus*, and more rarely *Stipa spartea*. Where this formation touches the bluestem formation, there is necessarily an intermingling of facies. Secondary species of grasses are very much the same for both formations: *Eragrostis pectinacea*, *Panicum Scribnerianum*, *Aristida oligantha*, *Koeleria cristata* and *Eatonia obtusata* are usually more abundant in the beardgrass type. Of other secondary species, in addition

to those enumerated in the blue-stem formation, are *Helianthus petiolaris*, *Potentilla arguta*, *Argemone alba*, *Plantago Purshii*, *Linum rigidum*, etc.

The blowout formation is restricted to peculiar crateriform hollows formed by the action of the wind, and termed "blowouts." In its young and typical condition, it is the most open of all plains formations. It occurs, of course, only in the sand hills proper, since it is here only that blowouts are formed. The facies of the formation are *Redfieldia flexuosa*, *Muhlenbergia pungens*, *Eragrostis trichodes*, *Oryzopsis cuspidata*, and *Calamovilfa longifolia*. The colonization of a recently formed blowout is brought about by means of *Redfieldia flexuosa*, which is uniformly the first grass to make its appearance in these hollows of shifting sand. The slight stability imparted to the sand by it enables *Muhlenbergia pungens* and *Eragrostis trichodes* to secure a foothold. These are followed by other grasses, and then by such secondary species as *Tradescantia Virginica*, *Eriogonum annuum*, *Meriolix serrulata*, *Lathyrus ornatus flavescens*, *Phaca longifolia*, and *Euphorbia petaloidea*. By this time the sand of the blowout has ceased to shift, and a host of ordinary sand hill inhabitants appear, resulting in the complete reclamation of the blowout and the decadence of the formation which characterized it. The process of reclaiming a blowout is very gradual, and the period between the incipience and the decadence of such a formation is often as much as ten years.

The sand draw formation has much in common with the blowout formation. It is less frequent, however, and is not so well characterized. Oddly, the grasses are not the controlling species. Their place is taken by *Cristatella Jamesii*, and *Polanisia trachysperma*. In a typical sand draw, the grasses are represented only by scattered tufts of *Munroa squarrosa*, *Eragrostis major*, *Sieglingia purpurea*, and *Paspalum setaceum*. The most frequent secondary species are *Euphorbia petaloidea*, *E. hexagona* and *E. montana*.

The foothill formations are three, (1) the undershrub formation of table lands and bad lands, (2) the mat and rosette

formation of buttes and hills, (3) the grass formation of high prairies and sandy plains. The undershrub formation is not peculiar to the foothills of the prairie province; it here covers but a small area in comparison with the vast stretches occupied by it in the Great Basin province. In the foothills, this formation exhibits two types, the one confined to high, somewhat grassy table lands, the other found solely on alkaline lands, or bad lands. The former may be termed the sagebrush type, the latter the greasewood-white-sage type. The facies of the sagebrush formation are *Artemisia tridentata*, *A. frigida*, *A. filifolia*, *A. canadensis*, and *A. cana*, *Chondrophora Howardii*, *C. nauseosa*, and *C. Douglasii*, and *Gutierrezia Sarothra*. The grasses are species of *Bouteloua*, *Agropyron*, and *Koeleria cristata*. The facies of the greasewood-white-sage formation are *Sarcobatus vermiculatus*, *Eurotia lanata* and *Atriplex confertifolia*. Grasses are practically absent. Other secondary species are few. *Ptiloria tenuifolia*, *Aster multiflorus*, *Cryptanthe Fendleri*, and *Chrysopsis villosa* are the most important.

In the foothills of the central portion of the prairie province, the mat and rosette formations are the most widely distributed. Mats and rosettes have almost exclusive control of buttes, cliffs, rocky ridges, and sandy hillsides. Two types may be distinguished, the mat formation of buttes and cliffs, and the rosette formation of sandy hillsides. No well-marked group of facies is regularly present. The ground-tone of the mat formation is derived from a large number of mat-forming species, *Arenaria Hookeri*, *Gilia spicata*, *Orophaca caespitosa*, *Eriogonum cernuum*, *E. flavum*, *Gilia iberidifolia*, *Phlox Hoodii*, and *Homalobus montanus*. The secondary species are for the most part invaders from the sand hills, such as *Meriolix serrulata*, *Malvastrum coccineum*, *Rumex venosus*, *Psoralea lanceolata*, *Aristida purpurea*, *Muhlenbergia pungens*, etc. The rosette formation takes its character from *Polygala alba*, *Paronychia Jamesii*, *Pentstemon albidus*, *P. caeruleus*, *Phlox Douglasii*, and *Oreocarya suffruticosa*. This formation is, in reality, transitional between the mat and the grass formations of the foothills, and its secondary species are derived chiefly from them.

The grass formations are more or less intermediate between the sand hill and the foothill formations, and serve to connect the two regions. The facies are two, *Stipa comata* and *Agropyron pseudorepens* each giving character to a more or less distinct type. The Stipa formation predominates over high prairies, the Agropyron formation upon level, sandy plains. The first exhibits a striking group of secondary species, which, from their constant association, and the uniformly blue color of their flowers, lend a distinctive character to the formation. These are *Lupinus plattensis*, *Astragalus mollissimus*, *A. adsurgens*, *Spiesia Lamberti* and *Psoralea argophylla*. The Agropyron formation is much more open than the preceding, and is of a more indefinite type.

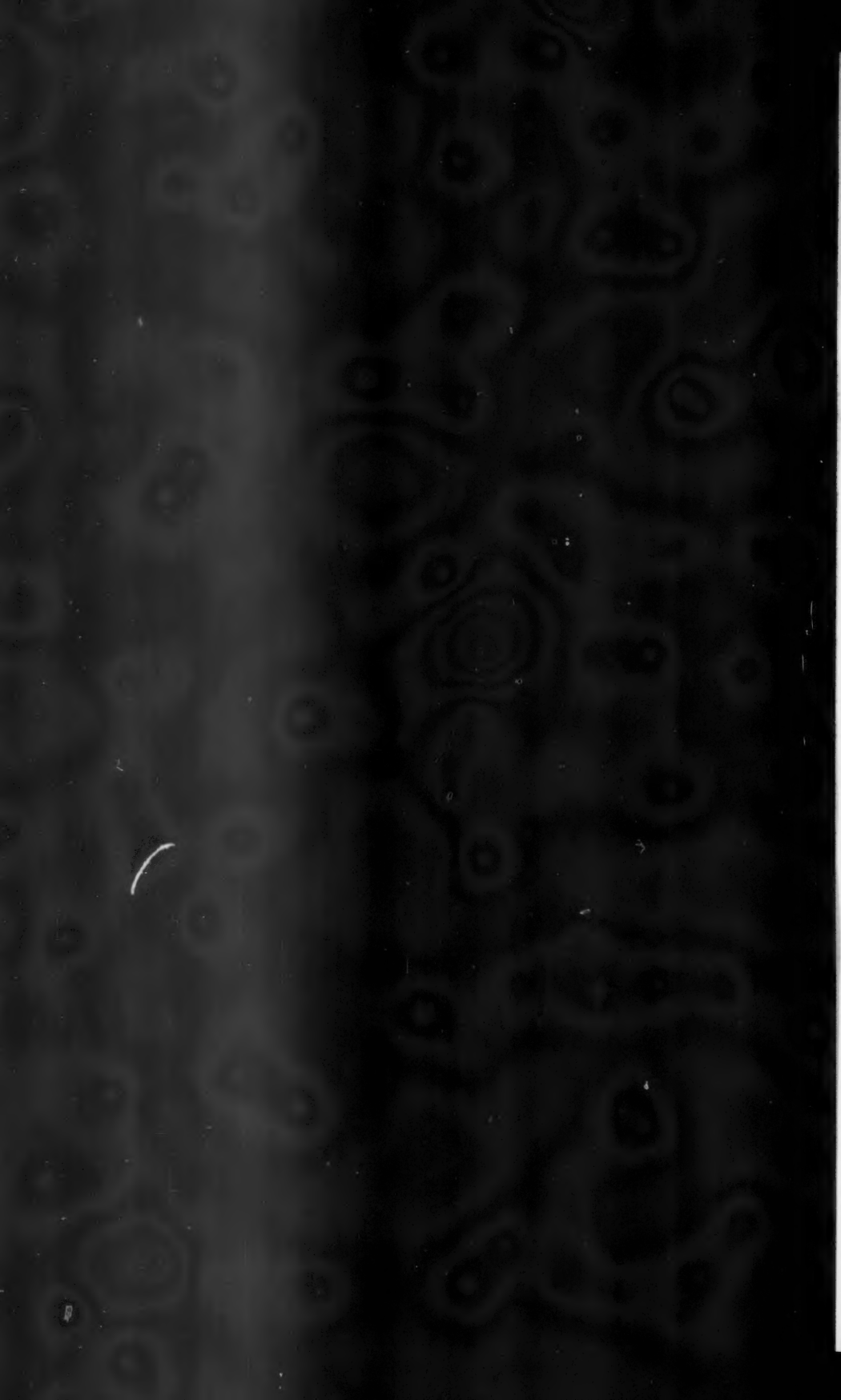
Halophytic and ruderal formations play a more or less prominent part in the constitution of the floral covering of the prairie province, but they are rarely characteristic, and hence scarcely within the scope of a short paper.

THE UNIVERSITY OF NEBRASKA.

EXPLANATION OF PLATE XXI.

Sketch map of the "Prairie Province:" I, the prairie region; II, the sand hill region; III, the foothill region.

POUND and CLEMENTS on PRAIRIE PROVINCE.



OBSERVATIONS ON THE NUTATION OF HELIANTHUS ANNUUS.[1]

JOHN H. SCHAFFNER.

IN the year 1890 Kellerman[2] reported some observations on the nutation of the sunflower, in which he concluded that, contrary to an almost universal popular belief, the heads of *Helianthus annuus* do not turn with the sun, facing toward the east in the morning and gradually moving westward until evening. He considered the belief mainly traditional, although he found some movement through a very small space, but rarely if ever through a space approaching a half circle. He suggested, however, that nutation might be more marked in the head previous to anthesis.

Having been a firm believer in the supposed nutation, and recalling numerous instances which seemed to support the belief, the writer desired to ascertain for himself the true facts in the case and also the conditions which may have given rise to the traditional belief. Accordingly a long series of observations were made in Clay county, Kansas, during the summers of 1896 and 1897, extending in both years from June to September. The summer of 1896 was especially favorable for the study, there being a more abundant and luxuriant crop of this characteristic western weed than usual. The western variety of *Helianthus annuus* differs considerably in many anatomical characters from the common cultivated variety which was not included in the study. The observations of the second season were entirely a confirmation of those recorded during the first.

[1] Contributions from the Botanical Laboratory, Ohio State University. II.

[2] Observations on the nutation of sunflowers. Trans. Kan. Acad. Sci. 12: 140–158. 1889–90.

NUTATION OF THE GROWING PLANT.

The observations were commenced on plants from three to five feet high, with stems varying from a half inch to an inch and a half in diameter. Observations were taken on a large number of individual plants, as well as on large patches of plants in general. In the morning, at sunrise, when the weather is clear, the plants all nutate toward the east or northeast at an angle of 45° to 75° from the vertical. The leaves stand out with rigid petioles so that their upper surfaces face the morning sun. When one stands looking toward the west, all the terminal buds and upper leaf surfaces face him. As the sun rises from the horizon, the plants gradually become erect and the leaves move at the same time so as to present their upper surfaces directly at right angles toward the rays of light. At noon the stems and terminal buds are vertical. During the afternoon the tops gradually nutate towards the west at an angle of 60° to 90° from the vertical. Usually the nutation is 90°. The upper surfaces of all the upper leaves have changed their positions so that they face due west and all those near the terminal bud have thus a more or less vertical position. The bending of the stem usually takes place about four or five inches from the tip and the curve represents merely the quadrant of the circumference of a circle, although sometimes it is more abrupt and angular (*fig.* 1).

By about 10 o'clock P.M. most of the stems have regained the vertical position, but at this time some may still be curved toward the west from 20° to 40°. The leaves now are turned downwards, drooping in such a manner that the apices all point vertically toward the earth. The curving is mainly in the petiole. This "sleeping" position contrasts quite strikingly with the day position, and it is taken both on cloudy and on starry nights. About 2 o'clock A.M., and usually much earlier, the leaves begin to be raised, and the tops of the stems turn toward the east gradually until sunrise, when they are again nutating from 45° to 75° toward the east.

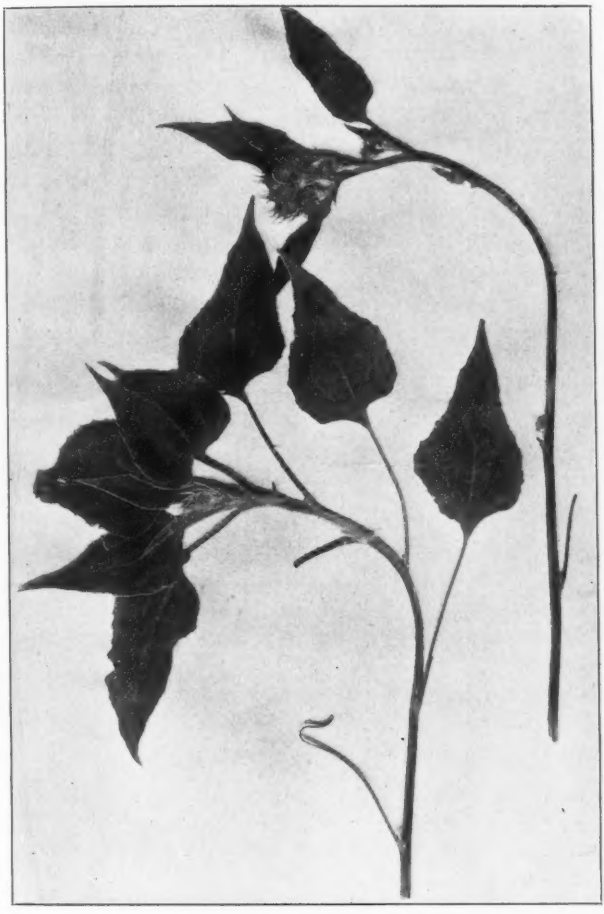


FIG. 1.—Two small plants of Helianthus showing westward nutation at sunset; photographed from pressed specimens with the natural curvature.

The following is a typical table of the nutation during twenty-four hours. July 11–12, 1897; two days after rain; sunshine and full moonlight throughout the period of observation; moderate wind from the northeast.

Time	Temperature	Angle of nutation	Direction	Remarks
5 p. m.	28° C	35°	West	Sunshine
6 p. m.	27	60	West	Sunshine
7 p. m.	24	75	West	Sunshine
Sunset				
8 p. m.	21	90	West	Full moon
9 p. m.	19	70	West	Full moon
10 p. m.	19	40	West	Full moon
12 m.	19	0	Vertical	Full moon
1 a. m.	19	30	East	Full moon
Sunrise				
5 a. m.	16	55	East	Sunshine
6 a. m.	17	70	East	Sunshine
7 a. m.	18	70	East	Sunshine
8 a. m.	19	40	East	Sunshine
10 a. m.	21	20	East	Sunshine
12 m.	22	0	Vertical	Fleeting clouds
2 p. m.	23	15	West	Fleeting clouds
3 p. m.	23	20	West	Fleeting clouds
5 p. m.	22	40	West	Fleeting clouds

There are thus four distinct periods in the daily nutation of the plant.

1. From shortly after sunrise, when the plant is nutating about 60° east, until sunset there is a gradual movement westward until the terminal bud faces west and the upper part of the stem nutates 90°.

2. From sunset until about 10 o'clock P.M., during which time the plant regains its vertical position and the leaves drop downward so that their apices point vertically toward the earth.

3. From 10 o'clock P.M. to 1 o'clock A.M., the period of repose.

4. From 1 o'clock A.M. until sunrise, a gradual turning eastward, accompanied by a rising of the leaves by which they are

again brought with their upper surfaces at right angles to the light.

Of course there is considerable difference to be observed in different individuals. Some regain the vertical position after sunset much sooner than others, and some begin to turn eastward long before 1 o'clock A.M. The nutations described here are not exceptional, but under ordinary conditions they occur in nearly all individuals, some nutating more prominently, however, than others. As soon as side branches are developed they partake of the movements to nearly as great an extent as the main axis.

If the bending of the stem and the diaheliotropism of the leaves is due to the direct stimulus produced by sunlight, then it is easy to see why the nutation should be considerably less in the morning than in the evening, since the light has much less time to produce the stimulus. But it may be that other causes have an influence on nutation. Thus at 11 o'clock P.M., while the leaves are all drooping, the crowns can frequently be seen turning toward the east which just two hours before were nutating 90° west. At 1 o'clock A.M., when it is evident no direct light can come from the sun, the tops of the stems are frequently seen nutating toward the east 30° or more, and the leaves are beginning to rise and stand up rigidly. Nor does it seem that the period of repose is brought on entirely by the falling of the temperature. From sunset until midnight there is a rapid fall in temperature, and during this period the "sleep" position is assumed. But there is also a rapid fall from 1 o'clock A.M. until sunrise, when the plant responds exactly in the opposite way. The drooping of the leaves then is not to be explained entirely as a means of protection against excessive radiation, for when the temperature is the lowest the leaves are already standing up rigidly and turning toward the east. Whether fluctuations in the humidity of the atmosphere had anything to do with this action, I did not attempt to investigate. I believe that this action is largely due to the fatigue of the protoplasm which must have expended an enormous amount of energy to keep up

the turgidity of the cells in the petiole during the day, and it resumes its work, after a period of rest, long before there seems to be any direct stimulus from the light.

EFFECT OF WIND, CLOUDS, DRYNESS, AND MOISTURE.

A moderate wind has little or no effect on nutation, no difference from what direction it comes. In Kansas the wind is very variable, but no important effect could be detected. However, when the wind blows very strongly it interferes somewhat with nutation. On some days when there was a very strong southwest wind the plants still turned west from 70° to 90°.

Cloudy weather has little effect on nutation. However, on some days it seems to check it a little. On some days, as for instance on July 27, 1897, it was cloudy nearly all the afternoon, but there was a strong nutation of 90° to the west.

Continued drought has a marked effect on nutation. When the ground is dry and the weather clear and hot the plants wilt, the leaves droop, and there is little or no nutation of the stem.

During rainy weather on cloudy days the nutation in the evening was scarcely noticeable. Also on a rainy day with sunshine in the latter part of the afternoon little or no nutation was discovered. When the ground was saturated with moisture and the atmosphere was very humid, although clear, very little nutation was observed. Thus in rainy weather, nutation is checked when it cannot be ascribed to a lack of sunshine. This was especially noticeable in the evening, but it was also very marked on mornings when the ground and atmosphere were saturated. When the ground is moderately moist and the air clear and dry with a light breeze, the conditions for nutation are at the optimum. At such times it is simply astonishing to notice a sunflower patch just at the setting of the sun. It thus appears that excessive moisture interferes greatly with the normal nutation of *Helianthus annuus*. This agrees with the observations of Cunningham,[3] who finds that plants react least readily to stimuli in a saturated atmosphere.

[3] The causes of fluctuations in turgescence in the motor organs of leaves. Ann. Roy. Bot. Gar. Calcutta **6** [Part 1, 4to. pp. 161]. 1895.

EFFECTS OF DECAPITATION, DEFOLIATION AND WOUNDING.

In order to determine through what organs the stimulus was received which caused the stems to bend, the terminal buds of a large number of plants were removed, and it was found that this treatment had no effect whatever, at least no noticeable effect, on the daily nutation. The decapitated plants acted in the same way as others not thus treated, nutating from 40° to 60° in the morning and from 60° to 90° in the evening. When conditions were favorable the decapitated plants nutated 90° west in the evening both on the day on which the operation was performed and for any number of days afterward.

Plants were also wounded by cutting slices from the side of the stem midway between the terminal bud and the central point of curvature, both on the east side and on the west. But this seemed to have no more effect on the nutation than would follow from the mechanical interference caused by the wound.

Plants were next treated by cutting off the leaves. In some the leaves were cut close to the stem, while in others the laminæ were cut off, the petiole being left. Plants thus treated immediately lost their power of nutation. They would stand perfectly upright, while their neighbors not so treated would nutate 90°. Some delaminated in the evening were found to be still inclining toward the west in the morning, while others had regained the upright position. When the leaves were cut in the morning the plants were found to be perfectly upright in the evening, while the natural ones and some decapitated the same morning nutated 90° west.

Thus it appears that decapitation has no effect on nutation. Wounding the side of the stem affects nutation only to the extent that it produces mechanical interference. Delamination, whether of the blade or of the entire leaf, stops nutation entirely. It was observed in some plants which had been delaminated that after the leaves and stems of the terminal bud had grown out again nutation was continued in the new parts, but the bending was confined to those parts and did not extend below.

From the above it is demonstrated that the irritability which is responsible for the bending of the stem is not inherent in the stem itself, but the stimulus is received by the lamina of the leaf, and the impulse transmitted through the petiole to the stem produces a response from both these parts.

NUTATION OF THE HEADS BEFORE ANTHESIS.

About July 15 the behavior of the young heads began to be observed. It was found that both the terminal heads and those on side branches nutated to the same extent as the leaf buds. Young heads on long, naked stems coming from the axils of leaves nutated also, the bracts of the involucre acting no doubt the same as the ordinary leaves. When the leaves were removed from the stems bearing heads, the nutation did not cease. Thus, on August 2 the leaves were removed from plants having young heads, and the next day these nutated 50° east in the morning, and 90° west in the evening. This experiment was repeated many times with both terminal and lateral heads, always with the same results. After the leaves have been removed from a plant having forty or fifty heads the effect of the nutation becomes quite striking.

THE DISK DURING ANTHESIS.

The nutation of the heads continues until anthesis begins. At this time the stem below the head hardens, which makes further nutation impossible. During anthesis the head is tipped sidewise until it stands with its face almost vertical, and this nodding is nearly always toward the northeast, although it may be east or north also. During favorable weather, at least 90 per cent. of the open disks will be found facing the northeast, both in the morning and in the evening. The heads are not disturbed by light wind, but a strong wind twists the stems and thus greatly disturbs the normal position of the heads. Whole acres of plants were observed in regard to these points. The eastward position of the disks readily deceives one into thinking that the face moves with the sun, especially when observations

are taken only in the morning. The nodding of the heads takes place about the time when the ligulate florets have all expanded; sometimes, however, it begins earlier. When the disk nods toward the northeast, the bracts of the head are brought with their outer surfaces into the most advantageous position for the process of photosyntax, and can thus continue to manufacture food which can no longer be transferred so readily through the elongated and hardening stem. This is of great advantage to the developing seeds of the large disk. There is also another advantage. The disk is turned away from direct sunlight, bringing the conditions to an optimum for the processes of pollination and fertilization.

Meehan[4] has observed an eastward turning of the heads of *Helianthus mollis*. He states that it has a southeasterly face on opening, and that it turns not with the sun but eastwardly as the head progresses toward maturity.

HELIANTHUS RIGIDUS.

During the summer of 1897, observations were also made on the nutation of *Helianthus rigidus*. Nutation in this plant is even more marked than in *H. annuus*. Young leafy stems and some with young heads were observed to nutate from 70° to 80° east in the morning and 90° west in the evening. The point of bending is quite low, usually about eight inches from the tip. Because of the naked and slender stems which bear the heads and the vigor with which they nutate, this plant should be an exceedingly favorable object for the study of curvature in stems, since it could be manipulated almost as readily as can the roots of seedlings.

COLUMBUS, OHIO.

[4] BOT. GAZ. 9 : 49–50. 1884.

ON THE MODE OF DISSEMINATION AND ON THE RETICULATIONS OF *RAMALINA RETICULATA*.

GEORGE JAMES PEIRCE.

SEVERAL years ago, Professor W. G. Farlow, of Harvard University, suggested my examining the thallus of *Ramalina reticulata* Krplhbr., with a view to determining the origin and mode of growth of the holes which give to this plant its characteristic appearance and its name. He generously allowed me to use all the material which was in the herbarium, but for various reasons I failed to obtain any results.

On coming here, I was surprised to find the white and blue oaks (*Quercus alba* L. and *Q. Douglasii* Hook. & Arn.) festooned with this lichen to such a degree that many even young and small trees are as hoary in appearance as old New England pines overgrown by *Usnea barbata* Fr.[1] The live oaks (*Q. chrysolepis* Liebm.) of this vicinity are seldom the resting place of other than fragments of nets torn by storm and wind from other trees and blown to them. As a rule, the evergreens, whatever the shape of their leaves, have fewer fragments or whole plants of Ramalina growing upon them than deciduous-leaved plants. It would be a long and useless task to determine the species of shrubs and small trees which, forming the thickets on the borders of the creeks, and composing the "chapparal" covering parts of the foothills, are draped more or less by large or small fragments of Ramalina which have been caught in winter by their leafless branches, or on which the younger nets have grown from the spore. The reasons why *Ramalina reticulata* is found hereabouts on deciduous-leaved trees and shrubs almost exclusively are obvious: namely, that there is less chance of fragments catching

[1] The accompanying figure shows a white oak overgrown by *Ramalina reticulata*. The photograph of which this is a reproduction was very generously taken for me by one of my students.

on branches covered by leaves than on bare and rough ones; and if any fragments should catch on leafy branches, they would receive less light during the winter rains than those hanging from unshaded branches, and hence, as the elaboration of non-

nitrogenous food by the gonidia would be less, so also the growth of the association of hyphæ and gonidia would be proportionally less. However, nearer the coast and southward, there is not this distinction, for this lichen grows on trees and shrubs of all sorts in that milder region, where during the dry and leafy season frequent fogs make some food manufacture and growth even then possible. About here it grows with little competition and attains a startling size, but there it is crowded by Usnea, Cladonia, etc., and remains, so far as my own observations go, much smaller in size. I have a fragment, collected very near here, which is twenty-six inches long, measured dry. There is no means even of guessing how much longer the whole plant would have been. So far as I know, this species of Ramalina is the longest lichen however, and as the breadth of the fragments is never very small in proportion to their length it may come near being the broadest also.

MODE OF DISSEMINATION.

By all means the commonest and most effective means by which *Ramalina reticulata* is reproduced and distributed is by larger or smaller pieces being torn by the wind from plants firmly attached, and carried to trees or shrubs, on the bare, rough branches of which the fragments catch and stay (fig. p. 405). As will be shown later on, this lichen softens to a remarkable degree when wet, it absorbs much water and greatly increases in weight, and its netted structure and branching habit cause it to be easily torn as it hangs down like a soft, delicate piece of gray-green lace, always longer than it is broad. When dry, it is hard, stiff, tenacious, and elastic, not readily broken by the wind. When wet, it is soft, pliant, not especially tenacious or elastic, and it is *much* heavier. As a rough index of the increase in weight during a hard and protracted rain the following figures will serve.

Fragment air dry weighed - - - 0.499 gr.
" soaked 15 min. in cold[2] water and surface dried by filter paper, weighed - - 1.020 gr.
Weight wet: weight dry = 2.04:1.

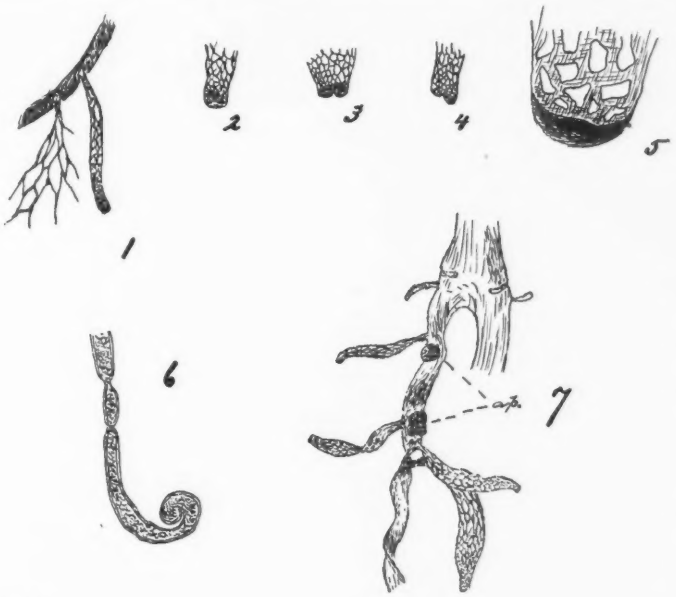
This increase in weight is less than that which would occur in nature, for more water would there adhere to the surface of the lichen than was left by the filter-paper. The increase in weight is furthermore unaccompanied by any immediate increase in strength,[3] for it is impossible that growth should occur so promptly or so rapidly as to keep pace with the increase in weight, although the wetting and consequent increase in weight take place more slowly in nature, even in a hard rain, than when the lichen is immersed in water in the laboratory.

The rains come only in winter, when the branches of many trees and shrubs are bare of leaves, and roughened by buds and barky excrescences. The rains are usually accompanied by wind, often high wind. It is therefore easy to see that the tearing away by the wind of fragments from the soft, heavy, pendant

[2] Cold water to avoid possible solution of gelatinous matter.

[3] For the actual decrease in strength see p. 415.

masses of lichen is inevitable, that the catching of these, often with a double twist which fastens them securely on bare rough branches, is very likely to occur ; and when the rain ceases, and



G.J.P. del.

FIG. 1. Two young thalli of *Ramalina reticulata* which have grown from spores on a small branch. The left hand thallus has been broken, the right hand one is younger and still intact. Natural size.

FIGS. 2, 3, 4. Ends of branches, showing narrower, backwardly rolled tips: 3 and 4 showing showing forking, in 3 with equal growth, in 4 with unequal growth of the branchlets, each with its own tip. × 3.

FIG. 5. Tip. × 15.

FIG. 6. Tip in section, showing circinate rolling. × 96.

FIG. 7. Part of a large thallus, showing apothecia (*ap*), and branches of various sizes, on the broad strands bounding a large mesh. Natural size.

the lichen dries, it contracts somewhat where it has been caught, as well as along its whole length and breadth, and so holds still more tightly to its support. It thus remains firmly fixed till the

next rain comes. It may be dislodged again, for such fragments do not form even the small weak holdfasts developing on specimens which have grown from the spore (fig. p. 407). The dislodgement is, however, less common than one would at first imagine ; *first*, because of the "double turn" which is so common, and *second*, because the part thrown around the branch remains more or less fixed in shape, conforming to the branch somewhat as a tendril does to its support. That there is anything more than a mechanical reason for this I doubt, although there may be contact or chemical irritation at this point ; for even when thoroughly wet, the part of the lichen bent or coiled around a branch does not uncoil or become very loose. Whether this is simply the fixing of a certain form by the growth, completed under mechanical stress, of the part of the lichen bent around the branch, or whether the growth is modified, directed, prolonged and finally terminated by the irritation set up by contact with the branch, I am not now able to say. Experiment only can settle this point, and experimentation with lichens is peculiarly difficult because of their slow growth. Against the idea that there may be irritation (contact or chemical), and a response thereto on the part of the hyphæ, is the fact that these hyphæ do not grow out from the lichen and attach themselves to the bark, there is no formation of anything like a new foot or holdfast such as the young lichen forms when growing from the spore. It is necessary, however, to consider the effect of contact with a branch not only upon the hyphæ which touch it, but also upon the the gonidia and hyphæ which may receive more or less nutritious solutions from the dead and decaying bark-cells. Observation leads to the belief that the fragment is simply caught by a rough branch, twisted about this by the wind, and remains there indefinitely, or until, during some subsequent rain, it becomes detached, falls to the ground, or is blown away to another branch.

The growth of any part of the lichen seems not to be impaired by detaching it from any other part. The fragments torn and carried away by the wind grow and fruit perfectly well ;

indeed it is a difficult matter (if possible at all) to find a whole fruiting specimen of *Ramalina reticulata*. I have not done so. The only specimens showing the holdfasts which I have been able to find, are small, the largest only seven inches long, (measured dry). Judging by the size of these holdfasts, it is hard to believe that they would grow strong enough to hold plants much longer; and of course the rest of the thallus is as weak as the holdfast, and that it breaks readily has just been shown.

Plainly then the usual and most effective mode of reproduction and distribution of *Ramalina reticulata* is a vegetative one, the rain softening the thallus and making it possible for the wind to detach pieces, even of considerable size, which are then carried (a large proportion of those detached) and fastened more or less securely by the wind upon branches of trees and shrubs, where the fragments thrive as if always undisturbed.

THE RETICULATED THALLUS.

The characteristic feature in the habit of *Ramalina reticulata* is, as the name implies, its netted structure. From the youngest and smallest to the oldest and largest, these Ramalinas are all of them nets. The youngest (and the young branches reproduce this) are shaped something like a narrow spatula (*figs. 1, 2*). Just behind the backwardly rolled and somewhat narrower tip, the flat thallus begins to be perforate, these perforations increasing in size to near the base of the thallus. There they are decidedly smaller, finally disappear, and the thallus contracts into a single thickened strand, which enlarges at the base. The stalk of a branch is very short and is confluent with the thallus (*fig. 7*, also *figs. 3* and *4* where branching is taking place). In the young Ramalinas which have grown from the spore, on the branches of trees, etc., the stalk may be somewhat longer and slightly broadened at the base into a small flattened, discoid holdfast (*fig. 1*). Since neither the stalk nor the holdfast keeps pace with the growth of the net-like part of the thallus, it is easy to see that the increasing weight of the last will sooner or later result in the lichen being broken or torn into two pieces.

This lichen does not form soredia. Other than the strictly vegetative mode of reproduction, which has been described in the foregoing, the only mode is by spores. The apothecia in which these are produced form on all older, though not necessarily oldest, parts. Either a very few comparatively large ones are produced on the flat, narrow strands forming the coarser nets, or a few still larger ones are scattered over the broad, usually short, plates, from which many branches spring, or finally a great number of small ones arise on similar, but older, broad expanses. The apothecia usually form on the flat surface rather than on the edge of the thallus, thus exhibiting a tendency directly opposite to that of the branches; but there are exceptions to both parts of this rule (*fig. 7 ap.*).

The origin of the holes in the thallus of this lichen has been discussed in several papers already. Of these I have been able to see only three, namely, Agardh's original papers,[4] in which he first describes the plant as an alga, and Lutz's.[5] In the last, various papers are cited. After summarizing and criticising the views of his predecessors, Lutz proceeds to describe his own experiments and conclusions. He worked only with dried herbarium material, and had never seen the plants in nature. His observations were, therefore, necessarily limited, and his results are naturally incomplete. Indeed, the obscurity and uncertainty regarding this lichen are due to the unnatural conditions under which small quantities of it have been examined, from the time when Agardh acquired some of it, supposed it to be an alga, and named it "*Chlorodictyon foliosum* (J. Ag. mscr.) Hab. . . . in Hb. J. E. Gray. (sine ulla de origine et loco adnotatione),"[6] until now.

Lutz calls attention to the gelatinous material in which the outer hyphæ are imbedded, and to the fact that, because of this, the outer parts at least will swell when moistened. He cut ter-

[4] (*a*) *Chlorodictyon.* Öfvers. af K. Vetensk. Akad. Förhandl. no. 5, 1870; and, (*b*) Lund's Univ. Arskr. **9**: 23. 1873.

[5] Ueber die sogenannte Netzbildung bei *Ramalina reticulata* Krplhbr. Ber. d. Deutsch. Bot. Gesellsch. **12**: 7. 1894.

[6] *Ibid. a.* p. 434.

minal portions from dry herbarium material, and measured the expansion which took place when water was brought into contact with them. He found that the expansion was from 20 to 43 per cent., and the more rapid the thinner the pieces. All parts, old as well as young, expand on wetting; all parts expand unequally if the water is unequally distributed over them; and if water is applied to only one side or edge of the thallus, or thallus fragment, that side will expand first and most, the transfer of water from part to part being comparatively slow. Such unequal expansions also occur in nature, because raindrops fall first on some parts, then on others, though during a rain-storm of longer duration all parts become uniformly moistened. The unequal wetting and consequent unequal expansions develop strains which tend to pull apart the thallus, the moist, soft parts pulling against and away from the dry, stiff parts in all directions. The majority of the hyphæ run longitudinally, the outer ones more regularly than those within; and the thallus is thin.

The result of wetting is that the thallus increases somewhat in thickness, more in length, and most (proportionally) in breadth. For example, a thallus branch, which I measured, was

$1\frac{13}{32}$ inches long $\frac{9}{32}$ inch broad	when air dry, - - - - - - -	35.7^{mm} 7.1^{mm}
$1\frac{23}{32}$ inches long $\frac{13}{32}$ inch broad	when soaked for 3 minutes in cold water, -	42.8^{mm} 10.3^{mm}

$\frac{9}{32}$ inch = increase in length = 7.1^{mm} = 20 per cent.
$\frac{4}{32}$ inch = increase in breath = 3.2^{mm} = 44 per cent.[7]

The most evident reason for this greater proportional expansion in the breadth is that the gelatinous material, on absorbing water, is met by less resistance to swelling outward (transversely) against the air, than longitudinally against other gelatinous matter and the hyphæ towards the tip and the base from the wetted part.

From the unequal expansions, the proportions of which I have roughly measured and indicated in the above table, Lutz

[7] The metric figures in this table are *calculated* from the figures in inches, which were obtained by *measurement*.

concludes that the perforations may readily arise by simple pulling apart of the generally longitudinally running hyphæ, adding that the breaks appear in the weakest parts of the thallus, namely in the thinnest parts, where the "bark" layer is virtually absent and where the spherical gonidia are most abundant (they are nowhere uniformly distributed), for in such places the hyphæ cannot bind them tightly together. This is true, but it is not all the truth. Microscopical examination of living material shows that the hyphæ are not merely in contact with the gonidial cells but are attached to them by haustoria which penetrate the cells,[8] and that the hyphæ bind the gonidia together in fairly coherent masses *except* when the gonidia have divided so rapidly that the young cells are not yet held fast by haustoria, though the mass and even individual cells may be enmeshed by hyphæ. The region of most frequent and most rapid multiplication of gonidia is that near, though not necessarily next to, the tip, and even in fairly old parts, such divisions of gonidial cells occur, and necessarily occur, if in these parts the hyphæ are to be adequately supplied with food-furnishing cells. To some degree in all parts of the lichen thallus, therefore, and most in the younger parts near the tips, there will be masses of young and small gonidial cells not yet held firmly by investing and penetrating hyphæ, and these masses will form the less coherent parts of the thallus, which can be more readily torn through by the unequal and mainly transverse expansions produced by unequal wettings.

But Lutz, though he mentions the peculiar tips of the branches of the thallus of *Ramalina reticulata*, overlooks the part they play in the formation of holes. The tips (*figs. 2, 3, 4, 5*) are narrower than the thallus just behind, and are rolled over. A section of the tip is crozier shaped (*fig. 6*). If a short branch, a few millimeters long, is put convex side down (that is, with the apex pointing upward) on a horizontally placed slide, and a drop of water put on the upper surface of the branch near the apex, the apex will be pushed forward by the longitudinal

[8] I shall discuss this in detail in a subsequent paper.

expansion of the thallus, but the youngest part will expand more, the apex itself will swell like the rest of the thallus in all three directions (in length, breadth, and thickness) and will bend upward slightly and then curve backwards somewhat over the thallus, thus straining the flat young part of the thallus just behind. But if the experiment be modified by placing a similar branch convex side down on a drop of water already on the slide, the apex will curl much more and much more rapidly, and thus the strain on the young parts just behind will be much greater. Because the apex is always narrower than the flat part of the thallus, and because it is always circinately curved, it cannot expand so much as the part behind. The young flat part is furthermore less coherent than either the closely rolled apex or the older flat parts farther back, because of the rapid multiplication of the gonidial cells and the consequently feeble attachment (if any) of the hyphæ to them. The apex then, in folding over, pulls the young flat part on the convex side, thus straining it longitudinally and inducing transverse ruptures in it. At the same time, the thallus is expanding transversely in the same part, but expanding most at a point not immediately behind the apex, for the narrower circinate, and, therefore, thicker apex opposes transverse expansion in the flat thin part closest to it. Precisely where the longitudinal strain is greatest, inducing transverse ruptures in the looser gonidial areas, there the transverse strain is also greatest, inducing longitudinal splits in the same gonidial areas.

Thus we see that it is not simply the expansion, or the unequal expansion, in three directions which produces the holes in the thallus of *Ramalina reticulata*, although this is the main factor in the older parts (where the formation of new holes is less frequent), but it is also the curving and consequent straining longitudinally of the softest and least coherent parts of the thallus, near the tip, by the folding over of the apex, and the concentration, owing to the narrowness and circinate curvature of the apex, of the greatest transverse strain in that zone where the longitudinal strain is also greatest.

Such experiments as those just described can be performed on intact thalli or larger fragments, either in the laboratory or in nature, quite as well as upon small pieces on the stage of the microscope. The dry thallus may not be able to retain the whole of a drop of water, but some of it will be held by the gelatinous outer part; there expansion will take place, and, if enough water has been held, curvature also. The nearer the tip the point is upon which the drop falls, the thinner it will be, the more prompt and the greater will be the expansion, the more pronounced the curvature, the greater the strain, the less coherent the structure of the thallus, the greater the likelihood of ruptures occurring in the weakest areas. Except when rain falls unaccompanied by any wind, and except in fog, the thallus is not likely to be uniformly wetted and in the former case uniform wetting would not be accomplished immediately. So in nature the conditions of expansion and curvature, as demonstrated by experiment, are normally realized.

Lutz says that drying after wetting brings about a change in the shape of the thallus, the length being greater, the breadth less, but the area the same as before the water was supplied; and that these contractions and changes in shape produce new and enlarge already existing holes. If such changes normally took place on drying, holes would result; but they do not take place. Lutz's method of experimentation is probably to blame for his conclusion. He used such small pieces of lichen that his experiments were conducted on the slide, under a magnification of thirty diameters. The moistened gelatinous matter on the surface of the lichen would naturally adhere to the glass somewhat, enough at least to prevent perfect contraction to the original form, and, as his fragments were several times longer than broad, there would be most adherence and least contraction longitudinally, which was what he found. I allowed the fragment which I had used for determining the expansion on wetting, in the experiment above reported, to dry quite free of such adherences by hanging it up. It contracted within five hours to

$1\frac{3}{32}$ inches in length = 35.7^{mm}
and $\frac{10}{32}$ of an inch in breadth = 7.9^{mm}.

that is, to the same length exactly and to within $\frac{1}{32}$ of an inch of the original breadth.

Two more points should be noted in connection with the the formation and enlargement of holes; namely, the relative tensile strength of the lichen when dry and when wet, and the part played by growth. I have made tests of which the following may be taken as the average. A piece of thallus with large holes bounded by stout filaments and bands was hung, tip downward, from a hook of small iron wire (not so fine as to cut the lichen quickly. This hook passed through a hole in the mesh and the part above appeared to be of average strength. From a similar hook similarly placed below were suspended weights. The breaking strength of the two strands which held the hooks was 150 grams when dry. The lichen was then soaked for fifteen minutes in cold water and hung up again, after the surface water had been removed. I tried to select for the support of the wire hooks two strands of size and position as nearly as possible the same as before. The strands broke with a weight of 30 grams, 20 per cent. only of the weight carried when dry. The experiment is rude and has evident faults (for instance, the strands are not of uniform strength under like conditions, hence in testing dry the strongest strands may be used, thus leaving absolutely, as well as relatively, weaker ones for testing wet; and the whole thallus had probably been weakened by weighting dry, hence it was weaker when wet than it ordinarily would have been); but it has some value in indicating the quality if not the quantity of difference in tensile strength under the two conditions.

This experiment indicates the longitudinal tensile strength. The transverse tensile strength must be less. Microscopic examination of sections, and unsectioned but cleared fragments of the thallus, shows, as before stated, that the hyphæ run mainly longitudinally in strands, fewer obliquely, almost none exactly transversely. Evidently the transverse tensile strength,

both dry and wet, would be less than the longitudinal. But I have shown that the length of a piece of thallus increases about 20 per cent. on wetting, whereas the breadth increases at least twice as much. From these figures we must infer that the transverse tensile strength must be much less when the thallus is wet than when it is dry. What the proportions are is not important.

These experiments and considerations show that, when the lichen thallus is being most strained by expanding and bending, it is also becoming weakest, namely when it is wet.

Growth, whether equal or unequal in different parts, would tend to enlarge those holes already formed. The growth of the longitudinally-running hyphæ, which form the strands bounding or between the holes, would lengthen these strands and cause them to bound larger holes. Unequal growth in young parts where holes had been formed either not all or only in small numbers, would produce strains favoring, if not wholly causing, the formation of holes at the points of greatest weakness. Growth takes place only when and where the lichen is wet and therefore mechanically weak. Growth would be unequal if the distribution of water in the thallus were unequal. That growth is unequal is evident from the fact that only very limited parts of the thallus are flat. The water-supply of different parts of the lichen will frequently be unequal, growth will therefore necessarily be unequal, growth strains will be unequal, the thallus will be most strained in weakest parts, these weakest parts will therefore be made still weaker. The growth of the new gonidial cells formed by the division of old ones will weaken and strain the part of the thallus where they are. If the growth of hyphæ and gonidia does not accomplish the formation of holes in the weakest parts, it at least facilitates it, and the strains produced afterwards by wetting, expanding, and curving, will do so. But growth is notoriously slow in lichens, and hence it cannot be an important factor in the formation of the holes as compared with the purely mechanical effects of wetting.

This explanation of the mechanics of hole formation presupposes the peculiar structure and composition of the thallus as a whole and the peculiar structure and mode of growth of the apex. Why the apex is consistently narrower and circinately inrolled, why the gonidia are distributed as they are, these are questions not answered by this mechanical explanation. They remain for further physical and physiological examination.

LELAND STANFORD JUNIOR UNIVERSITY.

A CONTRIBUTION TO THE LIFE HISTORY OF EUPHORBIA COROLLATA.[1]

FLORENCE MAY LYON.

(WITH PLATES XXII–XXIV)

INFLORESCENCE.

THE inflorescence of *Euphorbia corollata* is of the complicated form known as a cymose umbel. From the axils of bracts on the main stem of the inflorescence there arise three to five branches, each terminating in a smaller inflorescence called a *cyathium*, still occasionally referred to as "a flower"[2] (*figs. 12, 13, 14*).

These branches in turn produce bracts with axillary branches and terminal cyathia, and so on through four, five, or rarely six generations of branches (*fig. 14*). As the secondary and tertiary branches of the inflorescence develop, there is a tendency to diminish the lateral members, so that the ultimate branching may become dichasial. Again, all the terminal cyathia on the branches preceding the penultimate may be lacking.

THE CYATHIUM.

The cyathium has every external appearance of a perfect, complete flower (*fig. 12*). The involucre of five white bracts looks like a gamopetalous perianth. At the entrance to the tubular portion are developed five glands, which, together with five delicate outgrowths of the involucre, nearly block the passage. Within this involucre and opposite its component bracts are five groups of staminate flowers. A group commonly consists of three members, and each staminate flower is a single stamen terminal on a pedicel, and distinguishable exter-

[1] Contributions from Hull Botanical Laboratory. X.

[2] BAILLON: Histoire des plantes 5 : 109. 1874.

nally from a stamen only by a slight joint which marks the insertion of filament upon pedicel. In the center of the inflorescence arises the pistillate flower, distinguished also from a pistil by a joint in its axis. It is made up of three carpels forming a trilocular ovary with a single suspended anatropous ovule in each chamber, and a style with three deeply bifid branches. Masses of glandular hairs envelop the base of the pistillate flower, forming a dense screen between it and the staminate flowers. After fertilization the pedicel of the pistillate flower grows with great rapidity, carrying it far out of the involucre (*fig. 12*).

ORGANOGENY.

The first trace of the cyathium is a papilla-like outgrowth between two bracts which are themselves in the axil of a larger bract (*fig. 1*, and the bud shown in *fig. 12*). Near the base of this papilla there soon appear five protuberances (*fig. 2*), the forerunners of the involucre. In their axils arise the oldest staminate flowers (*fig. 3 s*^{1}). Simultaneously with these, and shortly before the appearance of the carpels, the three ovules are distinguishable on the outer rim of the papilla (*fig. 3 o*). The three carpels develop independently from the main axis above the oldest staminate flowers, which, at the same time, give off near their bases branches which are the second generation of staminate flowers (*fig. 4*). The carpels grow rapidly, their adjacent edges coalescing and turning inward as they develop, in such a way as to enclose each of the three ovules in a separate compartment (*fig. 7*). A third set of staminate branches spring from the pedicels of the second, and occasionally a fourth from these (*fig. 5*). The notch marking the boundary between filament and pedicel appears when the stamen is nearly mature (*fig. 5 s*^{1}).

A regular perfect flower does not develop thus. Stamens arise acropetally from the flower axis, and not as branches from stamens of a preceding generation, as is evident here from the course of the bundles. The resemblance of a single cyathium to a reduced inflorescence of exactly the same type as

the whole cluster (*fig. 14*) is very marked, as may be seen by comparing the fibro-vascular bundles in the dichasial group of staminate flowers in *fig. 5*, with the diagram of the main inflorescence in *fig. 14*. If in the latter, the terminal flowers after the first be suppressed, and the second, third, and fourth branches produce but one branch each, the resulting arrangement would be strictly comparable to that which obtains in the cyathium of *E. corollata*. The tendency of the terminal flower of the cyathium (*i. e.*, the pistillate) to disappear is marked, about one in ten having either a very rudimentary flower as in *fig. 15*, or no trace of one at all. The cyathium of *E. corollata* may be interpreted then as a much reduced inflorescence, made up of certain ultimate branches of a more complex inflorescence, possibly of simple flowers, which is still undergoing reduction.

MEGASPORANGIUM AND MEGASPORES.

The very young ovule stands nearly erect in the lower part of the loculus (*fig. 6*). It develops in such a manner as to become recurved, the loculus becoming more roomy by an intercalary growth of the base of the carpel and the funiculus. The stalk of the ovule, too, becomes elongated, until finally the ovule is suspended and anatropous, with the micropyle close to the funiculus and the raphe running along the inner edge (*figs. 6–11*). The development of the two integuments may be traced by the figures; the inner one appears first on the outer surface of the ovule, and is closely followed by the second, which soon surpasses it (*figs. 7–11*).

The embryo sac develops by the usual stages. A single hypodermal cell is differentiated from its neighbors and cuts off a primary wall cell (tapetum) (*figs. 18–20*). This is followed by a division of the primary sporogenous cell into an axial row of four mother cells, the lowermost of which develops into the sac (*figs. 21–24*). The cells of the nucellus, and possibly of the epidermis near the upper end of the sac, divide with great rapidity, producing a long, slender neck and leaving the sac deeply situated (*figs. 22, 23, 25, 26*).

A mass of active, glandular hairs develops on the placenta above the funiculus. Some of these apply themselves to the inner face of the nucellar neck, which bends toward them as it continues to lengthen (*figs. 11, 26, 52*). By the time the embryo sac is in the eight-celled stage, the tip of the neck has reached the narrow apex of the loculus and is closely appressed to the placental tissue (*fig. 52*). The integuments envelop it, and the outer one becomes attached to the placental tissue in such a manner as to enclose the neck completely. An axial row of cells, larger and of looser structure than the surrounding tissue, is developed through the entire length of the neck (*figs. 26, 52*). These connect with a line of glandular cells that leads through the placental tissue to the stigmatic surface of the style (*fig. 52*). The pollen tube thus has a definite and direct passage to the modified cells in the neck, which break down as it approaches.

The extremely long synergids hang from the upper end of the sac with the oosphere suspended between their free tips (*figs. 27–29*) in the direct path of the pollen tube which passes between them (*fig. 30*). The fusion of the polar nuclei takes place near the egg in either the longitudinal or the tranverse axis of the sac (*figs. 27, 28*). The antipodals are very ephemeral, having been seen but once in several hundred slides. The endosperm nucleus does not divide before the egg is fertilized (*fig. 30 end. n.*). Immediately after the entrance of the pollen tube, the neck of the nucellus and the glandular hairs disappear, and the outer integument closes the mouth of the micropyle with a little cap that develops from its inner edge. At the time of fertilization, when the embryo sac has encroached on the nucellus to the base of the ovule, the tissue in this region divides into a mass of small but comparatively thick-walled cells, forming a floor upon which the sac rests (*fig. 11*).

MICROSPORANGIUM.

When the stamen is but a small swelling (*fig. 3 s*^{1}) there appear in four distinct regions, approximately equidistant from

one another, plates of hypodermal archesporial cells (*figs. 30, 31, 32*). All of these divide once to form axial rows (*fig. 32*). These rows are radially placed, forming a mass of cells shaped like a truncated cone with its apex inward. Of the cells forming the inner layer, only a limited number, and, as a general thing, but one becomes the ancestor of the spore mother cells (*fig. 33*). The outer layer divides at once into two layers, thrusting the primary potential sporogenous cells down where there is even less room to divide (*fig. 33*). Among these one cell soon may be distinguished by superior size and different stain as the forerunner of the spore mother cells referred to above. The hypodermal layer of cells divides by periclinal walls into two layers (*fig. 34*). The tapetum is developed from the wall, and is frequently differentiated some time before the mother-cell stage (*fig. 34*). The development of the spore mother cells (*fig. 36*) and a clearly defined synapsis stage (*fig. 37*), with the usual division into tetrads, follow (*figs. 38–40*), In one preparation the mother cells had divided into fives and sixes instead of tetrads (*figs. 42–46.*) Nothing was observed to suggest how they were formed. It may be noted from the figures, however, that unlike the cases of Hemerocallis described by Juel,[3] the spores are of the same size.

The ordinary sequence of events leads to the development of the pollen grain, which is a spherical body with three deep grooves running from pole to pole. A large vegetative and a smaller lenticular generative nucleus were seen in the pollen grain and in the tube, but no trace of a division of the generative cell preceding tube formation (*figs. 48–51*). The pollen tube, with one generative cell and the vegetative nucleus, were frequently seen in cross sections of the peculiar nucellar neck, which led to the inference that either the generative cell may not divide at all, or if it does, one of the male cells disappears before the pollen tube enters the micropyle. The actual fusion of the gametes was not observed.

[3] Cytologische Studien aus dem Bonner Botanischen Institut. 51–72. 1897.

SUMMARY.

The "flower" of *Euphorbia corollata* is an inflorescence of the same type as the general inflorescence or cluster of which it is a unit. This is shown not only by the rudimentary development of perianths about the "pistil" and "stamens," but more emphatically by the fact that the order in which the organs develop is not that of a flower, but of an inflorescence.

2. This inflorescence, or cyathium, shows a marked tendency to become reduced still further by the disappearance of its carpellate flower in the approximate ratio of one to ten.

3. The development of the ovule is marked by an elaborate outgrowth of the nucellus into a long neck whose direction of growth is guided by placental hairs which exert an attractive influence, causing it to bend toward them and in this way making a complete connection between the stigmatic cells and the embryo sac for the passage of the pollen tube.

4. Ovules appear before there is any trace of carpel, being clearly of cauline origin.

5. The synergids are remarkably long, and the antipodals so ephemeral that only once were they discovered in several hundred preparations. This suggests the possibility of their having been overlooked in certain instances where they have been reported as absent.

6. As a rule but a single cell becomes the ancestor of all the spore mother cells in a single pollen sac.

7. The tapetum may be clearly differentiated, at least one division preceding the pollen mother cells. It is developed from the wall.

8. Abnormal cases of five and six spores instead of tetrads were observed.

9. The synapsis stage was found with perfect regularity.

10. Evidence was obtained suggesting that the generative cell may not divide.

THE UNIVERSITY OF CHICAGO.

EXPLANATION OF PLATES.

PLATE XXII.

The figures, with the exception of *figs. 15, 16, 17*, are diagrams. In all others, unless otherwise indicated, the optical combination was Reichert ocular 4 and Bausch and Lomb $\frac{1}{12}$ oil immersion. The drawings have been reduced to three-eighths of their original size as drawn with the Zeiss camera.

FIG. 1. Young bud of a cyathium of *E. corollata* with no differentiation of flowers.

FIG. 2. Same older, showing developing involucre (*i*) in axils of bracts (*b*). Vascular bundles in this and succeeding figures indicated by dotted lines.

FIG. 3. Still more advanced stage, in which five staminate flowers (s^1) have developed in the axils of the involucral leaves; the free margin of the papilla is slightly elevated into three ovules. Two cyathia of a younger generation are shown in the axils of the bracts (*b*).

FIG. 4. Ovules more advanced (*o*). Carpels have appeared at the bases of the ovules (*c*). A second group of staminate flowers, each of which is a branch from the staminate flower just above it (s^2). Involucre enclosing all flowers.

FIG. 5. Carpels about to unite with axis of flower. A mature staminate flower (s^1) with a notch marking the insertion of the filament upon the pedicel. Staminate flowers of the second, third, and fourth generations showing the dichasial arrangement. The gland (*g*) and ingrowing flap are developing on the inner margin of the involucre, while the five free petal-like parts are turning outward. In this, as in the preceding figures, *b* indicates the two green leaves which envelop the cyathium.

FIGS. 6–10 show the shifting position of the ovule from nearly erect to an anatropous suspended position. The two integuments are shown in each figure, the inner appearing the earlier.

FIG. 11. The nearly mature ovule with the nucellar neck bent toward the glandular hairs on the placenta. The shape of the embryo sac and the pad of thick walled small cells at the base of the nucellus are shown diagrammatically.

FIG. 12. Habit sketch of a cyathium after fertilization of ovules. A younger cyathium is developing in the axil of one of the green bracts that enveloped the older cyathium during its growth.

FIG. 13. Ground plan of cyathium.

FIG. 14. Diagram of main inflorescence, a cymose umbel.

FIG. 15. Portion of an abnormal cyathium in which no pistillate flower has developed.

FIGS. 16, 17. Abnormal staminate flowers; one with accessory anthers developed at the notch (*fig. 16*), the other with a cup-like perianth in the same situation (*fig. 17*).

PLATE XXIII.

FIGS. 18–20. Young megasporangia, showing first division of primary archesporial cell into tapetal and primary sporogenous cells, In *fig. 19* the primary tapetal has in turn divided, as has also the adjacent epidermal cell.

FIG. 21. Next stage in mother cell row.

FIGS. 22–24. One-celled embryo sac with remnant of mother cell row above and marked development of nucellar tissue in this region.

FIG. 25. Two-celled embryo sac; nucellus dividing further, and epidermis forming two layers of cells.

FIG. 26. Four-celled embryo sac; several glandular hairs with their conspicuous nuclei applying themselves to "neck;" differentiation of axial row of cells into so-called "channel cells;" portions of the two integuments shown in outline.

FIG. 27. Eight-celled embryo sac; the elongated synergids with the egg between their free tips lie in the upper part of the narrow sac; the polar nuclei fusing; the ephemeral antipodals.

FIG. 28. Polar nuclei fusing in transverse axis.

FIG. 29. The upper end of the sac in the eight-celled stage showing the relative positions of the synergids, the egg, and the endosperm nucleus to the "channel."

FIG. 30. Fertilization stage; pollen tube with male gamete passing between the disintegrating synergids toward egg lying beneath; the endosperm nucleus has not divided.

PLATE XXIV.

FIG. 30*a*. Young microsporangium showing one cell of archesporial plate differentiated.

FIG. 31. More advanced stage.

FIG. 32. Microsporangium showing two of the four plates of archesporial cells; one undergoing division.

FIG. 33. Still later stage, where the hypodermal layer seen at the right of *fig. 32* has divided, thrusting the layer under it down toward the center of the anther; only one cell in each of the conelike masses gives evidence of becoming the ancestor of the spore mother cells.

FIG. 34. A stage in which the tapetum is differentiated; about twelve sporogenous cells, ten of which show in the section.

FIG. 35. Later stage; tapetum not yet differentiated.

FIG. 36. Spore mother cell stage; tapetum developed.

FIG. 37. Synapsis stage.

FIG. 38. Stages following synapsis.

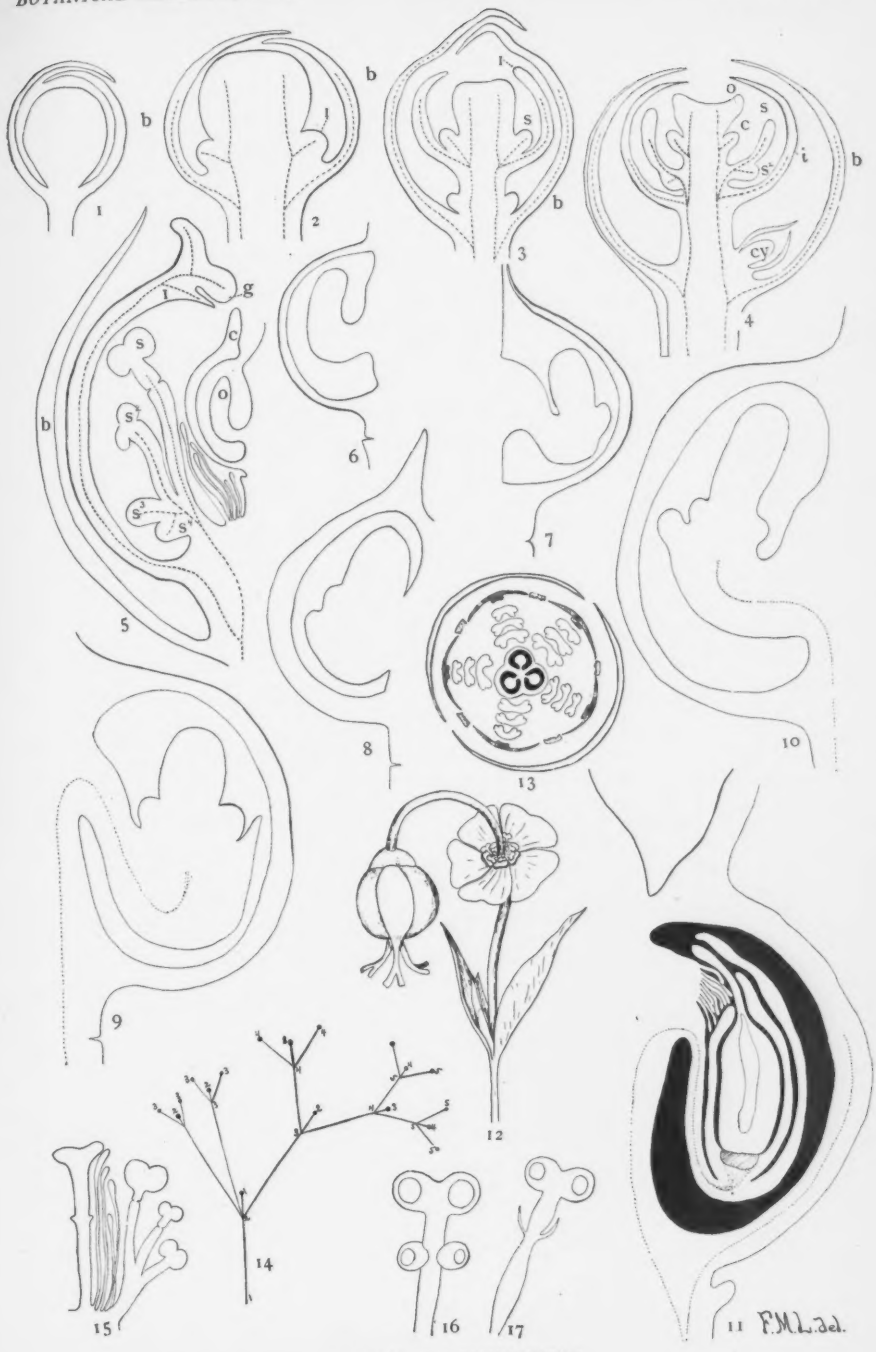
FIG. 39. Division into tetrads.

FIGS. 40, 41. Formation of microspores.

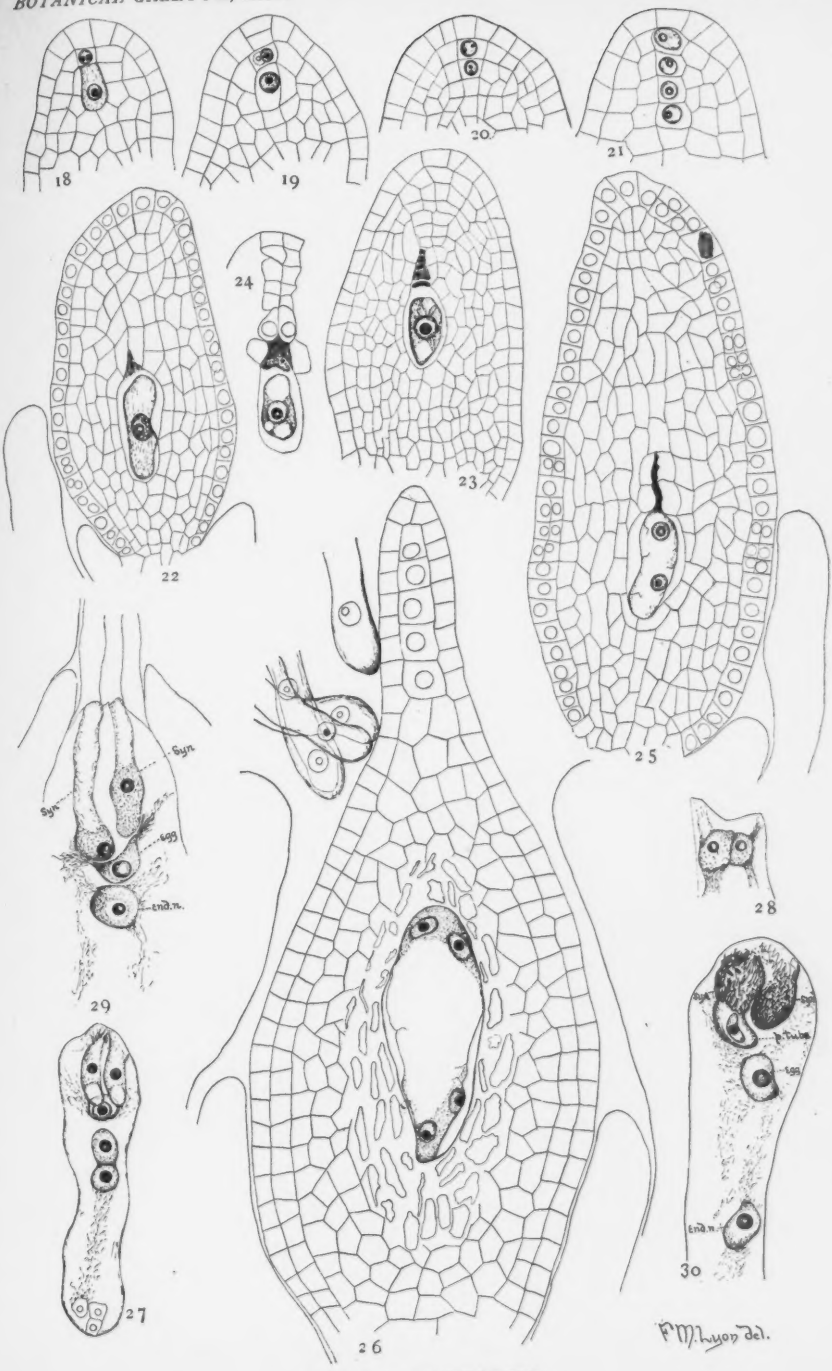
FIGS. 42–46. Irregular division into five and six spores instead of tetrads.

FIGS. 47–50. Development of pollen grains and division of nucleus into a larger vegetative and a smaller lenticular generative nucleus.

FIG. 52. Diagram of pistil showing relation of stigmatic surface, path of pollen through placenta, and connection with channel in neck of nucellus leading to embryo sac.



LYON on EUPHORBIA.



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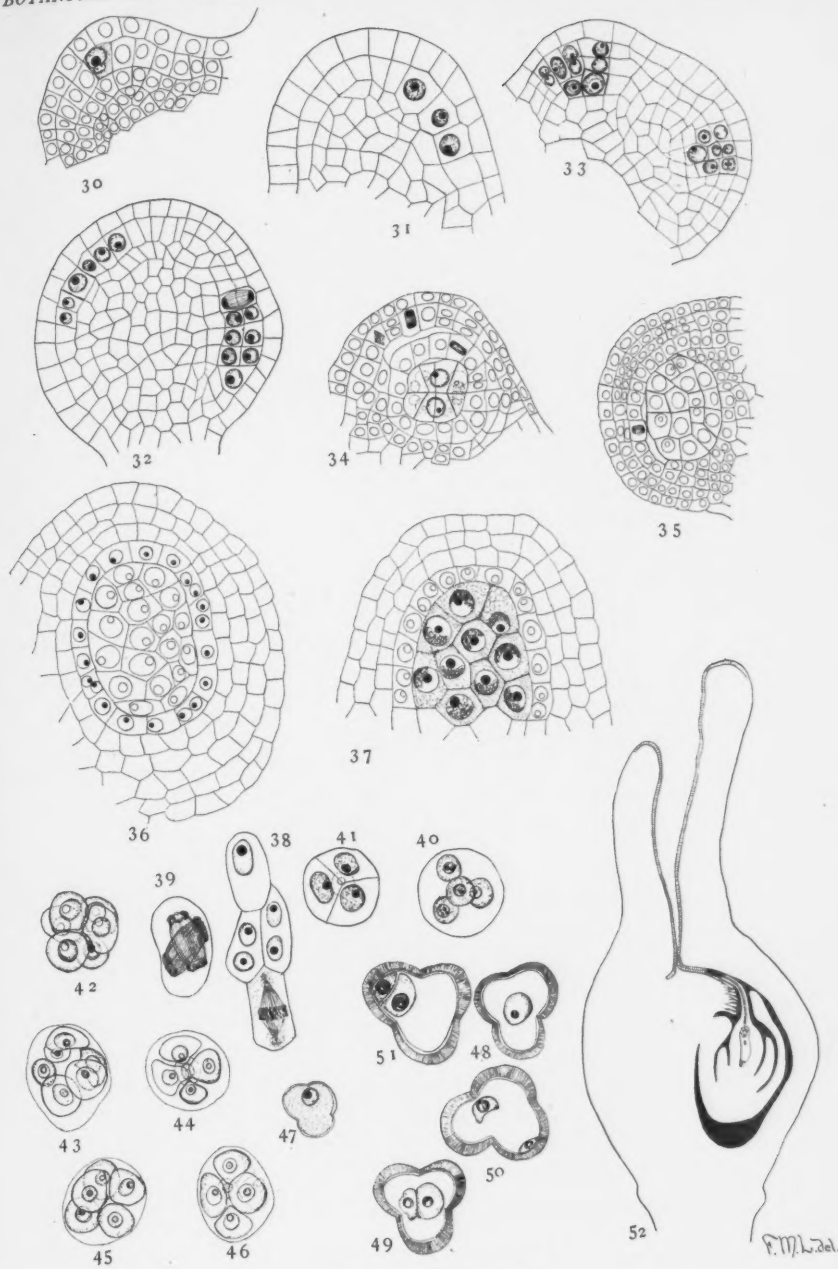

LYON on EUPHORBIA.

A BIOLOGICAL NOTE ON THE SIZE OF EVERGREEN NEEDLES.

EDWIN BINGHAM COPELAND.

THE profound influence which a prevalence of favorable or unfavorable weather in any season exerts upon the growth of stems is a matter of universal observation. Inadequate nutrition of the plant may be expected, and in general will be found to find expression in a more or less stunted development of both internodes and leaves; though in individual cases this parallel influence may be concealed by the different response of the two members to variations in light or moisture, acting as stimuli.

The best specific instance, with which I am acquainted in literature, of the effect of imperfect nutrition upon the growth of leaves, is in a brief note by Reinke,[1] who measured, on young trees of a number of species of Pinus and Abies, the length of needles formed (*a*) the year before the trees were transplanted, (*b*) the year when they were transplanted, and (*c*) the second year thereafter. In consequence of injury to the roots during transplanting, the needles formed during that year were materially shorter than those of preceding or following seasons.

Gregor Kraus[2] observed that the length of the needles varies from year to year[3] under the influence of "Boden und Klima," and mentions several instances: as one, in which the size of the leaves of deciduous trees is affected by the different illumination of different parts of the tree; and another in which,

[1] Berichte d. d. bot. Gesells. **2**: 376.

[2] Abhandl. d. naturf. Gesells. zu Halle **16**: 363. 1886.

[3] *Ibid.* 365. "Die absolute Länge der Nadeln eines Triebes hängt mit der Kräftigkeit des Jahrestriebes überhaupt zusammen. In günstigen Jahren werden bekanntlich sehr lange und kräftige, in ungünstigen viel kleinere und schwächere Triebe gebildet, und die Kräftigkeit oder Schwächlichkeit gilt nicht bloss für die Achsen, sondern auch für die Blätter."

the strength of the tree going largely to the fruit, fruiting apple trees bore smaller leaves than sterile ones. From a prevalent occurrence of shorter needles on the youngest year's growth, and from direct measurements, Kraus advanced the doctrine of a further growth in length of the needles of Pinus after the first year; which Meissner[4] and S. Honda,[5] from a mass of negative results deny. From his numerous measurements Meissner recognized the variations from year to year, and seems to regard this observation as one of his most important results.[6] But though he mentions in one place (*ibid.* 217, 1897) the effect of a dry summer in the growth of short needles, he introduces without explanation the fact that the variations on the main stem and on its branches are parallel, and expressly contradicts Kraus' statement that there is a relation between the length of the stem and that of the needle. As illustrating and emphasizing the influence of the conditions of vegetation on the development of leaves, the following notes may be of interest, although their most conspicuous feature is that already chronicled by Reinke.

In the spring of 1896 a considerable number of evergreens were transplanted to the campus of Indiana University. The most of these are still living, and except in the case of *Pinus Strobus* still bear leaves three, four, or more years old. I have measured needles from two or more plants of each species and in the appended tables present a fair average case of each. In every instance the needles formed during 1896 are conspicuously shorter than those of 1895 or 1897, giving the young trees a very odd appearance. The per cent. of shortening varies of course in the different plants, according to the injury they sustained in being moved.[7] The greatest decrease present in the tables is 74.6 per cent. on *Pinus Austriaca*. A still greater effect

[4] Bot. Zeit. **52**[1]: 55. 1894, and **55**[1]: 203. 1897.

[5] Not seen. Ref. Bot. Centralb. **67**: 25.

[6] Loc. cit. 217. 1897. "Die Nadeln nehmen von Jahr zu Jahr an Länge zu, dann ab, dann wieder zu, etc."

[7] REINKE, loc. cit. *Abies brachyphylla*, transplanted without injury to the roots, showed no change in the needles.

was observed in many instances; in fact it not infrequently occurred that *no* leaves were formed during 1896, the apical bud having remained almost dormant through that year, and grown again normally in 1897. Since it was the weakness of the trees as a whole that found expression in the stunted needles, it was bound *a priori* to show itself alike on all stems and branches, of whatever order, and I have thought it worth while to show this only in table IV. It was equally to be expected that such profound variations in the strength of the plants would affect the stems and the leaves alike, and as all the tables show, this was found to be true. In some cases the effect was most marked in the leaves, in others, notably Taxus, in the stems.

The growth of the stem in thickness was likewise uniformly checked. Thus in all cases the annual ring formed in 1896 was appreciably thinner than that of other years; which indeed was to be expected, as merely an unusually dry season is able to leave its record in a thinner ring. The leaves formed in 1896 were not only shorter but less in diameter as well, as is shown by the area of their cross sections. The leaves measured were among the largest of each year's growth. The measurements were made by drawing the outlines with a camera lucida on paper of uniform thickness and cutting out and weighing the sketches.

On trees set out in 1897 (table VII) it was of course that year in which the needles were dwarfed in length and diameter, and the annual ring remained thin.

While the shorter stem-segments of the season following transplanting bore also shorter leaves, they were much more densely beset by them; so that in most of the tables the total number of needles formed is found to have been greatest in that year.[8] I forbear to offer any hypothetical explanation of this interesting phenomenon. The number of needles compensates the plant for their lack of size, sometimes furnishing an even

[8] MEISSNER sometimes confuses the internode with the year's growth in length. The internodes are much more conspicuously shortened after transplanting than is even the year's growth, since their number is commonly increased.

greater surface of leaf than is borne on the normal year's growth of stem.

As clearly noted by Kraus, and emphasized almost humorously by Meissner, the length of the needles formed during different years on *uninjured* trees varies considerably with the prevailing climatic conditions. This appears undisturbed only in table VIII, which is introduced rather to show what might have been expected during these years, of the smaller trees, if their development had not been interrupted. There is absolutely no reason for suspecting an automatic periodicity in the length of the needles. These constant yearly fluctuations can only be regarded as less conspicuous symptoms of the same general state of matters which when exaggerated finds expression in the various phases of dwarfing of transplanted trees. In the latter case, that of transplanted trees, if we seek to apply the old "law of the minimums" it is probably safe to say (overlooking the possibility that this is in part an instance of "correlation") that the inability to get a proper supply of water is the factor which places the limit on growth. This must often be true, too, when the variations depend on the "Klima;" and the summer of 1897 (see table VIII) was indeed a destructively dry one in Bloomington. But the early part of the same season was unusually cold, and what part of the failure of the needles to reach their average length was due to the drought, and what to the late spring, cannot be said. To analyze the complex of conditions comprehended under a season's "weather" is not immediately practicable.

Even in the relatively simple case of transplanted trees Reinke probably went astray when he attempted any further analysis of the cause of dwarfing. He satisfied himself, in some way, that enough water was absorbed through the periderm of the old roots to cover the loss by transpiration, and concluded therefore that the normal development of the leaves is in part dependent upon the root pressure. Very probably it does depend upon the amount of water present within the plant; but before one ascribes a share in it to actual root pressure, it should

be shown that there is some pressure under normal conditions, present throughout the season of active growth; or that the length of the needles varies—as the root pressure probably does, if present at all—with the distance from the ground.

Since the variation from year to year, like the disturbances following transplanting, depends upon the general condition of the tree, it is self-evident that they will be the same on the main axis and on all its branches.

The most casual observation shows that in this climate the needles or leaves formed during any year are at first very short, afterward longer, and at the end of the season again short. In measuring the needles to find the average length for each year, it was immediately apparent that the progression in the length of the needles was surprisingly uniform. The first lines of figures in the individual tables show this almost as forcibly as plotting the curves would do. Each measurement is the average of ten successive needles, except in the instance of *Pinus Austriaca*, in which ten pairs of needles were taken. The figures at the beginning of each line represent the lowest needles on the year's growth of stem. Ten leaves taken each time is too many to show the curve in any detail when the year's growth bears as few leaves altogether as in the instances of Tsuga and Taxus; but on branches so conspicuously dorsiventral the leaves borne on the under side are so much longer than those above that taking a smaller number each time yields too broken a curve. The series of needles still clinging to stems more than three years old is usually quite incomplete, but except in one or two cases I have been unable to see that the shorter needles were cast off before the longer.[9]

The numbers representing the needle lengths advance each year from the spring minimum to a maximum, usually near the middle of the yearly growth in length, and then decrease to the fall minimum, which is usually lower than the first one. In many of the tables there is no break in the rise or fall, and what

[9] S. HONDA, loc. cit.: On species of Pinus he found the smallest leaves formed latest each year, and seldom clinging more than one year to the stem.

irregularities do appear in others are insignificant. The curves plotted from these data are at least as regular as can be obtained from actual measurement during the season. And while the causal connection of the two curves is not actually demonstrated, I do not doubt that both represent the same thing, the different vital activity at different seasons, as the plant gradually arouses from its winter rest in spring and sinks into it in late summer and fall. The tree keeps its own record of its annual period of activity in the length of its needles; and we do very well if the record we construct from continuous measurement of the rapidity of growth is equally legible.

The cause of this regular annual variation is the same complex, constituting its environment, which in some years stimulates the growth of longer, in others, of shorter leaves all summer; with perhaps a larger part played by the temperature, and less by the moisture, in the production of the rhythmic than of the irregular variations. How little the regular annual period depends upon present conditions, and how largely it is hereditary, in response to the climatic conditions of the plant's ancestors, cannot now be said, but it probably depends very much upon the species. No conclusions can be drawn from the Araucarias[10] in a local greenhouse, which show occasional zones of short leaves, corresponding possibly to periods of rest, for the greenhouse is only an attempt to reproduce their natural climate.

TABLES.

Except where otherwise specified, the measurements are made from lateral branches of the first order. In each table the average needle-length in successive zones, of ten needles each, from below upward, illustrating the regular yearly rise and fall in needle-length, is given first. Then follow the average *needle-length* of each year, the area of the *cross section* of a large needle, the length of the year's growth of *stem* (the same on

[10] DE BARY: Comp. Anat. 513. Annual rings are not always regularly present in the wood of Araucaria.

which the measured needles grew), and the thickness of the annual *rings*. The needles are measured in millimeters.

I. *Pinus Austriaca* Hors.

1895. 104.0, 106.4, 106.2, 104.2, 101.0 (11 pairs).

1896. 25.9, 27.7, 29.1, 29.6, 29.4, 28.5, 29.0, 29.1, 28.5, 28.3, 27.1, 25.2, 24.6, 23.9, 23.3, 23.1, 22.7, 22.2 (12 pairs).

1897. 107.1, 113.9, 112.8, 114.0, 114.0, 105.6 (12 pairs).

	Needle-length	Cross-section	Stem	Rings
1895.	104.36^{mm}	$0.864^{mm\ sq}$	22^{cm}	35 tracheides.
1896.	26.51	0.523	7.8	22 "
1897.	111.23	1.188	8.2	75 "

Though the response of the plant to its injury was more marked in this tree during 1896 than in any of the other trees represented by tables, its recovery by the next year was unusually complete, only the stem's growth in length seeming still to suffer.

II. *Pinus Strobus* L.

There were too few needles for their sequence to be instructive. In the growth of 1897 they were borne uniformly in fives; in that of 1896, often in threes or fours. Those of 1895 were all fallen.

	Needle-length	Cross section	Stem	Ring
1896.	59.57^{mm}	$0.227^{mm\ sq}$		0.189^{mm}
1897.	83.39	0.296		0.307

III. *Picea alba* Link. (*P.Canadensis* (Mill.) B. S. P.). Seven-year old tree.

1895. 9.0, 11.7, 13.9, 14.0, 14.8, 15.4, 15.5, 15.5, 15.4, 15.5, 15.1, 15.0, 14.4, 13.3, 12.3 (6 needles).

1896. 4.3, 5.1, 5.7, 6.2, 6.6, 7.1, 7.4, 7.8, 8.0, 8.0, 8.1, 8.4, 8.3, 8.3, 8.3, 8.2, 8.2, 8.0, 7.9, 7.7, 7.5, 7.4, 7.1, 6.8, 6.3, 5.7 (12 needles).

1897. 10.7, 13.5, 16.6, 17.6, 18.4, 19.5, 19.7, 20.2, 20.2, 20.4, 20.4, 20.3, 19.8, 19.6, 19.5, 19.1, 18.2, 17.8, 16.8, 14.9, 14.4, 12.6, 7.8.

	Needle-length	Cross section	Stem	Ring
1895.	14.05^{mm}	$0.418^{mm\ sq}$	15.3^{cm}	0.430^{mm}
1896.	7.25	0.262	6.7	0.185
1897.	17.30	0.600	14.0	0.298

IV. *Picea pungens* Engelm. About six years old.

1894. 13.9, 15.5, 15.6, 15.6, 15.8, 15.9, 15.4, 15.0, 14.8, 14.6, 14.3 (12 needles).

1895. 13.0, 15.1, 16.9, 17.0, 17.4, 17.5, 17.7, 17.4, 17.2, 17.1, 16.8, 16.5, 16.0, 15.6, 14.4, 12.9 (11 needles).

1896. 5.6, 7.5, 8.2, 8.5, 9.3, 9.7, 9.9, 10.0, 10.1, 10.2, 10.1, 10.3, 10.3, 10.4, 10.4, 10.5, 10.5, 10.0, 8.1 (7 needles).

1897. 11.7, 13.0, 13.9, 14.7, 15.0, 15.0, 14.9, 14.8, 14.7, 14.4, 13.8, 13.1, 12.4, 10.2.

	Needle-length	Cross section	Stem	Ring
1894.	15.13^{mm}		7.1^{cm}	
1895.	16.16	$0.847^{mm\ sq}$	8.2	0.262^{mm}
1896.	9.45	0.477	6.3	0.148
1897.	13.69	0.688	6.5	0.536

Branch of second order.

1895. 11.0, 12.9, 13.6, 14.0, 14.0, 14.3, 14.2, 14.1, 14.1, 13.6, 13.3, 13.0, 11.6 (14 needles).

1896. 4.7, 6.8, 7.9, 8.6, 8.5, 8.4, 7.6, 6.5, 4.9.

1897. 11.3, 12.6, 13.3, 13.8, 13.8, 13.7, 13.4, 13.1, 12.7, 11.9, 9.5 (8 needles).

	Needle-length	Stem
1895.	13.36^{mm}	6.2^{cm}
1896.	7.1	2.7
1897.	12.65	4.4

One year is not always sufficient for recovery from the injury of transplanting. Trees as young as these, if left to themselves, produce every year longer leaves than the year before. So the length in 1897 would naturally exceed that in 1895.

V. *Picea nigra* Link (*P. Mariana* (Mill.) B. S. P.).

1895. 7.7, 8.5, 9.6, 10.2, 10.7, 11.0, 11.4, 11.7, 11.9, 11.8, 11.8, 11.8, 11.8, 11.7, 11.5, 11.4, 11.1, 10.6, 10.4, 10.0.

1896. 3.4, 5.1, 6.3, 6.5, 6.8, 6.9, 7.0, 7.0, 7.0, 7.0, 7.1, 7.0, 7.1, 7.2, 7.0, 7.0.

1897. 7.6, 10.4, 11.5, 12.8, 13.3, 13.6, 13.6, 13.8, 13.7, 13.8, 13.8, 13.7, 13.7 13.4, 13.2, 12.9, 12.8, 12.6, 12.3, 12.2, 11.8, 8.4.

	Needle-length	Cross section	Stem
1895.	10.83^{mm}	$0.415^{mm\ sq}$	9.7^{cm}
1896.	6.59	0.222	4.3
1897.	12.50	0.409	8.1

The annual ring of 1896 was thinner than the others.

VI. *Picea excelsa* Link. Six-year old tree, transplanted in 1896.

1895. 14.4, 15.5, 16.1, 16.1, 16.5, 15.7, 16.1, 15.8, 15.8, 15.4, 15.6, 14.7, 14.3, 13.4, 13.2, 12.8 (12 needles).

1896. 8.2, 9.9, 10.9, 11.1, 11.3, 11.5, 11.6, 11.4, 11.3, 11.3, 11.2, 11.1, 11.0, 10.9, 10.7, 10.5, 10.5, 10.4, 10.0, 9.8 (11 needles).

1897. 15.8, 17.7, 19.3, 19.5, 19.7, 20.1, 20.1, 19.6, 19.7, 19.4, 18.8, 18.6, 15.8, 12.0, 10.6 (7 needles).

	Needle-length	Cross section	Stem	Ring
1895.	15.09^{mm}	$0.483^{mm\ sq}$	8.3^{cm}	0.325^{mm}
1896.	10.73	0.307	6.4	0.127
1897.	17.78	0.543	9.9	0.245

VII. *Picea excelsa* Link. Seven-year old tree, transplanted in 1897.

1895. 16.9, 19.1, 20.4, 21.5, 21.5, 21.2, 21.4, 21.4, 20.7, 19.1, 14.2 (5 needles).

1896. 12.8, 14.5, 15.8, 16.8, 16.9, 16.8, 16.8, 16.2, 15.6, 15.2, 14.6, 12.2 (14 needles).

1897. 6.2, 8.3, 9.0, 9.3, 9.6, 9.8, 9.8, 9.8, 9.6, 9.8, 9.6, 9.5, 9.5, 9.6, 9.1, 9.2, 8.9, 8.9, 8.7, 8.3, 8.0, 8.0, 7.8, 7.4, 6.7 (6 needles).

	Needle-length	Cross section	Stem	Ring
1895.	19.77^{mm}	$0.494^{mm\ sq}$	11.1^{cm}	0.300^{mm}
1896.	15.35	0.419	12.8	0.240
1897.	8.82	0.191	4.6	0.144

VIII. *Picea excelsa* Link. Tree about twenty-five years old. Lateral branch of second order.

1894. 16.5, 18.4, 19.6, 20.0, 20.3, 19.9, 20.4, 20.6, 21.0, 21.1, 20.8, 20.6, 19.6, 19.9, 18.5, 18.3, 17.9 (7 needles).

1895. 18.2, 21.8, 22.8, 22.4, 23.1, 24.0, 23.1, 23.1, 23.0, 21.7, 21.2, 19.7 (12 needles).

1896. 19.0, 20.1, 20.7, 21.1, 22.1, 22.3, 22.8, 22.3, 22.6, 22.2, 21.8, 21.8, 21.8, 21.1, 16.7 (13 needles).

1897. 15.5, 17.7, 18.6, 18.7, 18.6, 18.0, 18.2, 18.2, 18.0, 17.3, 17.6, 16.8, 16.0, 15.2, 15.2, 16.0, 12.9.

	Needle-length	Stem
1894.	19.61^{mm}	9.8^{cm}
1895.	22.01	10.0
1896.	21.23	10.2
1897.	16.97	11.0

IX. *Abies balsamea* (Linn.) Mill.

1895. 10.5, 13.1, 14.6, 16.2, 16.5, 15.9, 14.6, 13.9, 13.6, 12.3, 10.4.

1896. 6.5, 7.6, 8.5, 8.7, 9.0, 9.1, 9.2, 9.2, 8.9, 8.7, 8.9, 8.4, 8.1, 8.1, 7.5, 7.3, 6.8, 6.2, 5.7, 4.4 (8 leaves).

1897. 13.2, 15.6, 16.8, 17.2, 17.6, 16.8, 16.4, 15.7, 14.6, 14.0, 13.1, 9.5 (8 leaves).

	Needle-length	Cross section	Stem	Ring
1895.	13.78^{mm}	0.307$^{mm\ sq}$	10.9^{cm}	0.206^{mm}
1896.	7.84	0.354	4.4	0.07
1897.	15.04	0.477	6.3	0.115

X. *Tsuga Canadensis* (Linn.) Carr.

1896. 7.5, 8.1, 7.6, 7.3.

1897. 8.1, 9.2, 8.3, 8.1, 6.9, 5.9 (13 leaves).

	Leaf length	Stem
1895.	10.00^{mm}	9.2^{cm}
1896.	7.62	2.5
1897.	7.75	4.1

Many of the small dorsal leaves do not cling to the stem more than one year; hence the figures for 1895 and 1896 are too large in proportion to those for 1897.

XI. *Taxus baccata* L.

1895. 13.0, 16.9, 16.3, 12.7, 11.0, 9.9.

1896. 7.9, 8.4, 5.7 (6 leaves).

1897. 13.9, 17.2, 17.3, 14.9, 7.5 (4 leaves).

	Leaf length	Cross-section	Stem	Ring
1895.	13.3^{mm}	1.318$^{mm\ sq}$	8.3^{cm}	39 tracheids
1896.	7.58	0.773	2.1	6 "
1897.	15.07	1.045	8.2	20 "

INDIANA UNIVERSITY,
Bloomington, Ind.

SOME REASONS WHY THE ROCHESTER NOMENCLATURE CANNOT BE REGARDED AS A CONSISTENT OR STABLE SYSTEM.

B. L. Robinson.

Since the vivacious discussions of 1890 to 1895 comparatively little has been published in America upon botanical nomenclature. While this lull in the conflict between opposing and often too sharply expressed opinions is grateful to all concerned, the difficult and intricate nomenclature question is as far from settlement as ever. The subject may seem trite and tiresome, but the present divergent practices in naming plants are not only a source of great annoyance but offer a serious impediment to the successful advance of classification. The gravity of the whole issue is, therefore, so great as to justify every renewed effort toward a better general understanding of the subject, since this alone can lead to a final and satisfactory settlement.

Some years ago a number of our American colleagues, with conscientious efforts and praiseworthy intentions, devised and offered to the world a nomenclature reform, hoping that it would gain ground and soon meet with general approval and adoption. This, however, has not been the case, nor has its ill success been due to prejudice. While among its opponents there may have been some, it is true, who, with little knowledge of the subject, opposed the system merely because it involved changes of familiar names, there were others who objected to the Rochester nomenclature because it seemed to have certain inherent defects of a nature to preclude ultimate success. During the years which have passed since the Rochester and Madison meetings little effort has been made to correct these defects and the energy of the reformers has been largely devoted to establishing their code by putting it into immediate use in their publications and herbarium work. The fact that

this has been done in disregard of the opinions and expressed wishes of a very large number of their colleagues does not concern us here, except as showing an unfortunate over-confidence on the part of the reformers. What they should realize, however, is that no number of monographs or floras, published in accordance with the Rochester code, will establish a single principle or a single name, which does not appeal to future botanists as reasonable. Surely those who have themselves discarded hundreds of names which had stood unchallenged for nearly a century should not feel that they are establishing their system merely by putting it into use. The only way it can be established is by making it so reasonable and consistent that it will command general respect and approbation.

Readily accepting the now generally admitted fact that 1753 is the most desirable date of departure, the writer can see only two logical methods of codifying botanical nomenclature. According to the first of these modes, priority both of time and place must be unrestricted from the date of starting. Each plant must bear *its earliest designation*, and each name must be used *only in its earliest signification*. Such a system would involve a hitherto unprecedented change but is both conceivable and logical. The other method, while also recognizing the great value of priority in determining the proper names of plants, would seek to limit this principle by such qualifications as would be necessary to retain as great a part as possible of the current nomenclature. In the first or absolute system no exceptions can be permitted, usage may not be taken into account, and in fact nomenclature must be torn down to the point where it can be rebuilt with regularity and symmetry. The language of systematic botany must, in such a system, start almost afresh and follow unswervingly certain theoretical principles. In the other system, principles must also be sought out and followed, but here, like the rules of grammar, they should be based upon usage and derive their guiding power by stating, generalizing, and correlating usage and not by defying it. Either system to be effective requires a fairly general

agreement of botanists. It is not my purpose here to discuss the relative merits of the absolute and usage systems, for that has already been done *ad nauseam*. I merely wish to show that the Rochester nomenclature corresponds to neither of these systems; that it falls between them; and that while claiming to rest upon a firm basis of priority, it derives many of its principal names from usage and in defiance of a consistent priority.

Within the last few years two kinds of priority have been recognized, that of time of publication and that of relative position in a given work. The latter, "priority of place," is as definite and almost as necessary to an absolute system of reform as the more generally recognized priority of time. Both have been acknowledged principles in the Rochester reform, but the reformers in their application of the "priority of place" have been neither thorough nor consistent. While they have felt it necessary to discard many well-established names on account of this principle, they have failed to apply it when determining which of several species is to be regarded as the type of a genus. By way of illustration we may consider the Linnæan genus Erysimum, which, according to the theory of the Rochester code, dates from its treatment in the first edition of the *Species Plantarum*. Now in this work the generic name (unaccompanied by generic character) is followed by four well-known species, namely, *E. officinale* L. (*Sisymbrium officinale* Scop.), *E. Barbarea* L. (*Barbarea vulgaris* R. Br.), *E. Alliaria* L. (*Alliaria officinalis* Andrz.), and *E. cheiranthoides* L. It will be observed that these species are now relegated to four different genera, but strangely enough our reformers, while professing to follow priority as the "fundamental principle" of nomenclature, have selected not the first but the last species of the Linnæan genus to retain the name Erysimum. In other words, they have here abandoned the much-extolled principle of priority and have adopted one of usage. They have taken *Erysimum cheiranthoides* as the true type of the genus, not because it was the first species to bear that name, but because it was the species which had been so treated by subsequent usage. Nor is Erysimum an

isolated instance of this kind. The same departure from a strict priority has been made in the case of Sisymbrium, Erigeron, Poa, Senecio, Brassica, and in fact many other important genera.

Now I would not be taken as saying that usage is not a very excellent guide in such matters, but would merely emphasize the fact that if the Rochester nomenclature, in last analysis, really rests upon usage and not upon priority, it loses at once that absolute and decisive character which has been represented as its chief advantage. If we are not to have a consistent application of priority, why overthrow hundreds of established names to accomplish a reform? If priority is to be modified at all, why not restrain it effectively by some such excellent provision as the fifty-year limit of the Berlin botanists? Let us have either a nomenclature of consistent principles or one of maximum immediate convenience. As I have said, the Rochester nomenclature appears to be neither. It overthrows too much and fails to establish its new structure upon a logical basis.

I am quite aware that the American ornithologists have stopped in their application of priority at essentially the same point as the Rochester and Madison reformers. The ornithologists' nomenclature, however, possesses the advantage that their code clearly recognizes and defines this departure from its usual principles. The botanical code, on the other hand, wholly neglects to state any such exceptions, and accordingly the usage of the Rochester reformers is to this extent inconsistent with their own code. The exception in the case of the ornithologists has been accomplished merely by general agreement. Of course, if such agreement can be obtained, any system of nomenclature whatever, whether consistent or inconsistent, can be made serviceable. But no system which is not in itself logical is likely to stand the test of time.

It cannot be denied that to take any species other than the first as the type of a genus involves a grave inconsistency with the other principles of the reform.

The much advocated principle of "once a synonym always

a synonym," for instance, states that a name once applied in one sense may not be used subsequently in any other, and this directly affects the case in hand; for to return to the example of Erysimum, the first species of this genus was a Sisymbrium. In other words Erysimum was first employed to designate what we now call Sisymbrium. As we read down the 660th page of the *Species Plantarum* and arrive at the last line in the description of *E. officinale*, we have reached a point where the genus Erysimum has already been published. The needful generic name has been coupled with a definitely characterized and well-known species. If it is not a published genus when we have reached this point, why is any monotypic genus in the *Species Plantarum* to be so regarded? But Erysimum, thus established by the publication of its first species, applies only to what we now call Sisymbrium, and any transfer of the generic name to another genus, is not only opposed to "priority of place" but contrary to the principle of "once a synonym always a synonym," which expressly forbids such a change in the use of a name. The fact that Linnæus himself, further down the same page, published certain other species, which he considered congeneric, or that Erysimum was by later authors differently applied, should have to the mind of the consistent advocate of priority no weight whatever. In this connection I recall the words of Professor Britton :[1]

> I accepted Tissa rather than Buda for the simple reason that it stands first on the page in Adanson's *Familles*. That is priority, I am sure. The fact that Dumortier named some species under Budah as, to me, nothing to do with the case.

In the *Species Plantarum*, as I have above implied, there are many other important genera of like composite character, and interpreted by the reformers with similar disregard of their own principles. Thus the first Sisymbrium was a Nasturtium, and for those who would follow consistently the principle of priority of place, this should stand as the type of a genus Sisymbrium, which must embrace all our present species of Nasturtium, and

[1] Jour. of Bot. **19**: 265.

not be made, as by the reformers, the type of a subsequently published genus, Roripa.

It is needless to multiply such examples. Cases in point are many, so numerous, in fact, that the reformers, having gone thus far in the quest of priority, have suddenly been appalled by the amount of change necessary for further advance, and have, accordingly, with no word of explanation, abandoned the pursuit of the principle. But this is stopping the reform not at the goal to which its accepted principles lead, but arbitrarily, and just where it happens to be convenient, surely a disappointing outcome for such an ambitious and widely heralded revision.

This question regarding the type species of a composite genus is not new. It was well discussed by Mr. O. F. Cook[2] in 1895, when he urged, upon the basis of his studies in the Myxomycetes, that the only satisfactory solution was the uniform acceptance of the first species as the generic type. A subject so important to the Rochester reform should certainly have received the prompt attention of the Nomenclature Committee, but far from taking any definite or satisfactory action which could be a guide to others, the members themselves, as their divergent practices clearly show, have been quite unable to agree upon this point. The majority, it is true, still use Erysimum, Sisymbrium, Erigeron, etc., in their conventional meaning, but one member has boldly faced the issue and refuses longer to accept Erysimum in its old sense, since it is clear that its first species was a Sisymbrium. All our American species of Erysimum are accordingly transferred by him to Cheiranthus. This change is carried one step further in a recent American flora,[3] where we find that not only our Erysimums have gone to Cheiranthus, but Sisymbrium is called Erysimum. As each generic change of this sort implies the ultimate formation of many new binomial combinations, the end of this felicitous settlement of our nomenclature question is not yet in sight.

When questioned as to the uniform acceptance of the first species of a genus as to its type, advocates of the Rochester

[2] Bull. Torr. Bot. Club **22**: 433. [3] HOWELL, Fl. N. W. Am. **1**: 38–56.

reform have replied that such a course, while logical, would require *too* great change. It would appear then that the Rochester code is a clever device to bring us stability by causing *a great deal* of change, but not *too much* change. In his recent comments upon the Berlin rules,[4] Professor Britton propounds the momentous question: Who is to say whether *Elvasia elvasioides* involves tautology? It does not occur to him to ask: Who, in the American reform, is to make the refined distinction between *much* change and *more* change? Yet the two questions in their relative importance forcibly suggest a Berlin mote and a Rochester beam.

Besides this matter of the selection of the generic type, various other questions, relative to their nomenclature, seem as yet unsettled by the reformers. What, it may be asked, is the status of a generic synonym in the first edition of the *Species Plantarum?* Can it be neglected as a "pre-Linnæan" name? Certainly not, for it appears in print subsequently to the beginning of 1753, the date from which priority is reckoned. These generic synonyms, it may be argued, are not properly described, but for that matter the accepted genera of the same work are not described at all. Both, however, are clearly defined by the species. Now under *Psoralea Dalea* L., the name Dalea is used not solely as a specific name, but, a line or so below, as a generic synonym. In other words, even in "Linnæan" times, the first generic name applied to a Dalea was Dalea. Why then do our reformers feel it necessary to change fifty or more species of Dalea to the subsequently published genus Parosela of Cavanilles? Nor is this by any means the only instance in which generic synonyms in the *Species Plantarum* are likely to cause trouble. The name Pedicularis, for example, as it first appears on page 602, does not represent the genus to which it is now applied, but is a clear synonym of *Bartsia coccinea*, or as it is now called *Castilleia coccinea*. But, having once been applied to a Castilleia, how, without violence to the principle of "once a synonym always a synonym," can it be later used for a subse-

[4] Bull. Torr. Bot. Club **24**: 419.

quently published plant or group of plants? Such cases are far too numerous to be disregarded, and a consistent or scholarly code, starting from the *Species Plantarum*, should certainly contain a definite statement as to the Linnæan synonyms. The subject cannot be wholly neglected, for both radical and more conservative botanists have, on certain occasions, taken up names which had first appeared as synonyms, and used them to displace others of subsequent but more regular publication. Is such a practice justifiable in some cases and not in others?

While the object of the present article has been to deal rather with the principles than the details of the Rochester nomenclature, a specific instance may be cited to show that even where their principles may be perfectly clear, the reformers do not always live up to them. Of all the changes suggested by the Rochester reform, none has been more unfortunate than the transfer of Stellaria to Alsine. It involves not merely much specific change but leads to exceptional confusion from the circumstance that there is another large and nearly related genus Alsine, which the European botanists generally recognize and show no tendency to abandon. However, from the standpoint of the reformer, this is due to no fault of the Rochester movement, but merely to the perversity of those benighted individuals who as yet fail to accept the light it sheds. So, waiving for the moment all points relative to the justice and expediency of adopting Alsine for the greater part of Stellaria, I wish merely to defend certain residual rights of the latter genus. It is a long established fact in the common law of nomenclature that if a part of a genus is taken away, the rest must still bear the same name. Now the Stellaria of Linnæus contained two distinct generic elements, Stellaria and Cerastium, for the latter element is represented by *Stellaria cerastioides* L. (*Cerastium trigynum* Vill.; *C. cerastioides* Britton, Mem. Torr. Club **5**: 150, Britton & Brown, Ill. Fl. **2**: 28). The only reason why the reformers transfer our Stellarias to the Linnæan Alsine (a miserable generic failure, made up of *Stellaria media* and a Spergularia) is that Alsine appears on an earlier page of the *Species Plantarum* than Stellaria. But Stellaria has exactly the same

sort of priority over Cerastium, and if only a part of Stellaria goes to Alsine, the rest (its other generic element), namely *Stellaria cerastioides* L., must in all justice be retained to stand for Stellaria. Its arbitrary transference, as in the *Illustrated Flora*, to the subsequently published genus Cerastium, is out of the question in any system where "priority of publication is the fundamental principle of nomenclature." But if *Stellaria cerastioides*, according to priority of place, represents the valid part of Stellaria, all the numerous Cerastiums must be rechristened under Stellaria, unless the reformers find it possible to reexamine *Stellaria cerastioides* and decide that it is, after all, an Alsine, a course of procedure which would not greatly strengthen any system.

The facts here enumerated seem fully to justify the conclusion that the Rochester reform, notwithstanding the conscientious endeavors of its advocates, fails to offer a definite or final solution of the nomenclature question. It is perfectly evident that its application of priority, far from being consistent and universal, is subject to certain indefinite and unwritten restrictions, upon which even the reformers themselves cannot agree. The theory of an unrestricted priority from 1753 is most seductive, but it is now clear to many of its former advocates that, while causing much needless change, it secures in the end no greater definiteness nor finality than a priority limited, let us say by the fifty-year clause. Uniformity of practice can only be secured by agreement in any case, and while the fifty-year limit may well give an excellent basis for such agreement, unrestricted priority cannot yet be consistently interpreted by its most zealous advocates.

As former efforts to present in a clear light certain defects in the Rochester nomenclature have called forth prompt and in some cases wholly irrelevant criticism, it seems necessary to say, in conclusion, that the questions here raised regarding Erysimum, Sisymbrium, Nasturtium, Erigeron, Stellaria, Cerastium, etc., are definite difficulties, and as such cannot be satisfactorily answered, to an intelligent public by an unwarrantable accusation of personality nor by vague panegyrics upon priority in general.

GRAY HERBARIUM.

BRIEFER ARTICLES.

NOTES ON THE BOTANY OF THE SOUTHEASTERN STATES. III.

CRATÆGUS MACRACANTHA Lodd., Loudon, Arb. Brit. **2**: 819. 1854. [ed. 2.]—In the valley of the Swannanoa river, near Biltmore, North Carolina, this species has been located recently. The finding of this thorn in the mountains of western North Carolina reveals the existence of not less than thirteen distinct varieties of the genus in this part of the state. While it has been considered that "the headquarters of the genus Cratægus" are in eastern Texas and western Louisiana,[1] the state of North Carolina has at least sixteen species within its borders.

Cratægus macracantha in North Carolina is usually a much-branched shrub, but occasionally attains arborescent proportions. It blossoms two or three weeks later than *C. coccinea* L. and a few days before the small-fruited form of *C. tomentosa* L., referred to in my second paper, and to which variety it is evidently more closely related than to the scarlet thorn. The flowers are produced in broad, leafy cymes, and are much smaller and more numerous than in *C. coccinea*; the leaves, which are borne on stouter and shorter petioles, are narrowed or cuneate at the base, prominently veined and of rather firmer substance, and the fruit at maturity is succulent and smaller than in the last named species. I have aimed to draw direct comparisons between the long-spined and scarlet thorns to point out the great dissimilarity between the two species, and because the disparity in the descriptions of the former in several text-books of botany is most bewildering. I take pleasure in acknowledging material assistance and many notes concerning this confused genus from my associate, Mr. F. E. Boynton, who has been my almost constant companion for several years in botanical pursuits.

CRATÆGUS ROTUNDIFOLIA (Ehrh.) Borck. in Rœm. Arch. **13**: 87. 1798.—The recognition of this species removes another stumbling

[1] C. S. SARGENT, Silva **4**: 83. 1892.

block from our consideration of this puzzling, yet intensely interesting, genus. It seems that specimens of the above in herbaria have been generally placed with or referred to *C. coccinea* L., and while it has an aspect similar to that species it may be readily recognized. *C. rotundifolia* is abundantly represented in western North Carolina, growing along the banks of streams and even in the shallow, dry soil of old fields and upland woods. It frequently attains the size of a small tree, some 4–6^{m} high, and blossoms perceptibly later than *C. coccinea*, from which it may be distinguished by the very glandular character of the young shoots, thicker leaves, fewer stamens with usually lighter colored anthers, and the greenish or dull russet-red fruits.

CRATÆGUS ELLIPTICA Ait. Hort. Kew. **2**: 168. 1789.—A few miles west of Biltmore, North Carolina, this excellent species is abundantly represented in abandoned fields and in open woodlands standing in company with pine and oak timber. In such situations *C. elliptica* often attains the proportions of a small tree, and the spreading, slightly pendulous or recurved, zig-zag branches and branchlets give a strikingly distinct aspect that serves to distinguish the species readily even in winter. In the time of flowering *C. elliptica* is from ten days to three weeks earlier than *C. flava* Ait., which is not uncommon in the region, and, besides, differs from that species by its smaller flowers, larger fruit, broader, thicker, and more glossy leaves, and the pubescence covering the young shoots and foliage.

POPULUS BALSAMIFERA CANDICANS (Ait.) A. Gray, Man. ed. 2. 419. 1856.—Much uncertainty yet surrounds the natural limits of distribution of this fine tree. Professor L. H. Bailey[2] points out its existence in Michigan; but I fail to find further information of a definite character.

The pistillate, possibly the only known form, is commonly cultivated and sparingly spontaneous at Biltmore, N. C., and other southern points.

POPULUS ALBA L. Sp. Pl. 1034. 1753.—Along many water-courses in the vicinity of Biltmore, N. C., and elsewhere in the south *P. alba* is spontaneous. I have observed only the staminate form, but rapid propagation is effected by broken branches carried by streams and by excessive sprouting from the stoloniferous roots.

[2] BOT. GAZ. **5**: 77 and 91. 1880; and Bull. Cornell Univ. **68**: 220. 1894.

COREOPSIS LONGIFOLIA Small, Bull. Torr. Bot. Club **22**: 47. 1895. — Material that closely matches specimens of this species gathered near Jacksonville, Florida, has been collected in Bladen county, North Carolina, June 9, 1896. The plants from North Carolina are plainly of perennial duration and continue to blossom from lateral shoots and possibly by seedlings until autumn.

Coreopsis helianthoides, n. sp.— An herb 5–12^{dm} high from a perennial base, growing in the moist, sandy pine barrens of west Florida: stout furrowed stems glabrous and terete, very leafy to near the middle, but almost naked at the divergently-branched summit: radical and lowest cauline leaves 5–12^{cm} long, 2–6^{cm} broad, ovate to ovate-lanceolate, acute, scarious-edged, contracted at the base into long margined petioles and sparingly and inconspicuously hirsute on both surfaces with many-jointed weak hairs; upper cauline few and remote, linear-lanceolate, much reduced in size and passing into mere bracts; petioles dilated and clasping at the insertion by a short sheath: internodes from base to near the middle very short, 1–5^{cm} long: heads 3–18 in number, many-flowered, 3–4^{cm} wide including the rays, 1–1.5^{cm} high: outer involucral scales lanceolate, 5–9^{mm} long, 2–4^{mm} wide; the inner ovate, 8–12^{mm} long, 4–7^{mm} wide, many-nerved; floral scales linear, 5–7^{mm} long, acute: disk flowers dark purple; rays 8, orange-yellow, 3-cleft, the middle segment large and notched at the obtuse apex: achenes oblong, bordered by strong pectinate wings and surmounted by two short hispid awns.

C. helianthoides in general aspect is strikingly like *Helianthus Dowellianus* Curtis, and is related to *C. gladiata* Walt., from which species it differs in its smaller and more numerous heads, very leafy stem, remarkably short internodes, greater length of the outer involucral bracts, larger and acute leaves and much stouter habit.

The type specimens were gathered at Aspalaga, Florida, October, 1897, by Dr. A. W. Chapman, who recognized the form as probably new to science.

GERANIUM MOLLE L. Sp. Pl. 682. 1753.— This interesting fugitive is thoroughly established in waste grounds at Biltmore, N. C., forming on the surface of the soil mats that are very conspicuous and in fertile situations sufficiently large to cover an area 5^{dm} square. The first seeds ripen in this locality in May, and under favorable conditions a second crop of plants is produced which mature seeds in autumn.

GERANIUM DISSECTUM L. Amœn. Acad. 4 : 282. 1760.—This and the preceding species are not mentioned in text-books at my command as occurring in the southern states. *Geranium dissectum* blossoms at the same time or a little later than *G. Carolinianum* L., when the two species occupy the same area, and matures its first fruit as early as May. Not uncommonly a second crop of plants is produced that blossoms in autumn or late summer. The species is plentiful in waste places and cultivated grounds at Biltmore, North Carolina.

VIOLA TRIPARTITA Ell. Bot. S. C. & Ga. 1 : 320. 1817.—Dr. Small[3] has left little that may profitably be added to strengthen his most just attempt to restore to full standing this much confused and valid species. The affinities of *V. tripartita* are truly with *V. pubescens* Ait. and not with *V. hastata* Michx. Even in simple-leaved forms it is abundantly distinct from the last named species, and not only in the characters set forth in the article above referred to, but by the rootstocks, roots, and as it occurs in the south, by marked differences of environment. The short rootstock and long, coarse roots of *V. tripartita* are conspicuously different from the long horizontal and nearly white, fleshy rootstock and fine, short roots of *V. hastata*, and as found along the mountains and at Biltmore, N. C., *V. tripartita* grows in rather dry and fertile soil on the slopes of the hills or in shallow dales, while *V. hastata* selects a very moist or wet situation in woods and boggy or springy places on the sides of the mountains.

ACHYRANTHES ASPERA OBTUSIFOLIA (Lam.) Griseb. Fl. Brit. W. Ind. 62. 1864.—I have a specimen of this collected by Mr. A. H. Curtiss at Key West, Florida, and recently Dr. Chapman sent to the Herbarium specimens gathered in the streets of Apalachicola, Florida. It is evidently spontaneous at these stations and will doubtless be found at other southern ports.

PANICUM LONGIFOLIUM Torr. Fl. U. S. 149. 1824.—Material gathered near Wilmington, N. C., October 11, 1897, and recently verified by Mr. F. Lamson-Scribner, extends the range of this interesting grass many miles beyond the heretofore recognized limits. In this locality the species inhabits moist savannahs and margins of shallow ponds, growing in scattered tufts over a considerable area.

SYNEDRELLA NODIFLORA (L.) Gærtn. Fruct. 2 : 456. *pl. 171.* 1791. —Dr. Chapman has sent to the Herbarium flowering specimens of

[3] Bull. Torr. Bot. Club 24 : 494. 1897.

this species gathered during the summer of 1897 at Apalachicola, Florida.

HYDROCOTYLE BONARIENSIS Lam. Encycl. **3**: 153. 1788.—Another station in the United States for this fugitive may be added, the species being abundantly and thoroughly established in the vicinity of the ballast dumps at Wilmington, N. C., where it was collected in fruit and flower, July 2, 1897.

CAREX LAXICULMIS Schwein. Ann. Lyc. N. Y. **1**: 70. 1824.—On May 13, 1898, in Henderson county, North Carolina, *C. laxiculmis* was found with nearly mature perigynia. I believe this is the first record of the species as belonging to the southern flora.—C. D. BEADLE, *Biltmore Herbarium*.

A NEW SPECIES OF APIOS FROM KENTUCKY.

THE plant here characterized was discovered some years ago in open woods and thickets near Bowling Green, Kentucky, by Miss Sadie F. Price. After noticing for several seasons its occurrence and peculiar characters, Miss Price, who recognized its genus and believed it a new species, sent it to Professor Charles F. Wheeler of Michigan Agricultural College for further examination. Professor Wheeler, after making dissections and comparisons, concurred in the view that it represented an undescribed Apios, but with undue modesty has declined to characterize it, and Miss Price has recently referred flowering and fruiting specimens, together with careful drawings, to the writer. The species for several reasons possesses more than ordinary interest. It is a second American member of a small but well-known genus. Like its congeners it has farinaceous tuberiform roots, but these attain much more considerable proportions and suggest a possible utility in cultivation. Furthermore, the corolla has a somewhat peculiar form, the standard being provided at the apex with a thick, spongy, knot-like prolongation. Any homologue of this appendage which may exist in the other known species is so rudimentary, if present at all, that its occurrence here seems to warrant the separation of this species as a subgenus. The genus may thus be divided into two subgenera as follows:

EUAPIOS. Standard suborbicular, rounded or retuse at the unthickened summit. Roots (as far as known) fibrous or moniliform-tuberous.

—Including *A. tuberosa* Moench of Atlantic North America, and *A. macrantha* Oliv., *A. carnea* Benth., and *A Fortunei* Maxim. of Asia.

TYLOSEMIUM. Standard produced at the apex into a thickened spongy appendage. Root apparently single, irregularly spheroidal, and of great size.—Name from τύλος, lump, and σημεῖον, vexillum.—A single species, described below, which, notwithstanding the differences indicated, is obviously congeneric with the other species just enumerated under EUAPIOS.

A. Priceana, n. sp.—Vigorous herbaceous twiner: stem terete, slightly striate, at first covered with a fine reflexed pubescence, but

soon nearly glabrate, arising from a large oblate spheroidal root (18^{cm} in diameter): leaves 3–9-foliolate; those of the main stem 24^{cm} long, the ovate or ovate-lanceolate acuminate leaflets sparingly pubescent upon

both surfaces, green and scarcely paler beneath, thin and rather veiny, obtuse or rounded at the base, 4 to 10^{cm} long, half as broad; petiolules hirsutulous; leaves and leaflets of the branches considerably smaller; stipules subulate, pubescent, 6^{mm} long: racemes dense, borne mostly by twos and threes in the axils, those of the main stem often 12 to 15^{cm} long, 50–70-flowered and mostly bearing a single short branch; rameal inflorescences smaller and simple; floral axes thickish; pedicels slender, 5^{mm} long, commonly borne by twos and threes in the axils of ovate caudate-acuminate bracts of somewhat greater length: calyx hemispherical, roseate; the limb obliquely sub-truncate except for the linear-attenuate anterior tooth: petals greenish white tinged especially toward the end with rose-purple or magenta; the vexillum suborbicular, 25^{mm} long, bi-auriculate at the base and bluntly cornute at the apex; wings somewhat shorter, narrowly oblong, a little broadened and rounded at the apex: essential organs of the genus: pods clustered, 12 to 15^{cm} long, 1^{cm} broad, acuminate at the apex, attenuate at the base, about 10-seeded; seeds oblong, olive green, 8^{mm} long, separated in the pod by bi-concave sections of the silvery white pithy endocarp.—Collected in flower and fruit by Miss Sadie F. Price, in rocky woods, Bowling Green, Warren county, southern Kentucky. The type specimens are in the Gray Herbarium.

Miss Price reports that the species often fails to set fruit. She has observed that the flowers are visited by the butterfly *Eudamus tityrus* and by both honey bees and bumble bees, the latter appearing to find the nectaries very difficult of access. The accompanying illustration was drawn from life by Miss Price. It is a pleasure to commemorate in the specific name of this noteworthy plant the work of such a careful observer of the Kentucky flora.

The genus Apios furnishes still another instance of discrepancy between the theory and practice of the Rochester reformers. The generic name Apios, occasionally employed in prelinnæan times, was not used by Linnæus himself, but was revived late in the 18th century. In the meantime, however, Adanson founded his genus Bradlea (*Familles des Plantes* **2**: 324. 1763), which, as he himself states (p. 527), included the first two species of the Linnæan Glycine, namely *G. Apios* (now of the genus Apios) and *G. frutescens* (referred by the reformers to Kraunhia). The former species, cited first by Adanson and resting on a plate of Cornuti, duly mentioned in Adanson's brief description, must be taken as the type of Bradlea. But whether Bradlea stands for

its Apios element, or its Wistaria element, it is equally evident that the genus long antedates both *Apios* Moench. and *Kraunhia* Raf., which the reformers keep up for these two elements respectively. Bradlea is not obscure enough to be overlooked, since it is published in Adanson's well-known work from which the reformers have derived so many of their names. It is also duly cited as a synonym of Apios by such works as Pfeiffer's *Nomenclator* and Hooker and Jackson's *Index Kewensis*. It does not appear to be antedated by any homonym, and it is truly puzzling to see why it has been rejected by those who, as they claim, admit no exception to the law of priority. However, its revival at present would be worse than useless, until the value of the fifty-year limit, suggested by the leading German botanists, can be subjected to a careful test. Mention of Bradlea is here made merely to show how little finality the advocates of the Rochester nomenclature have been able to obtain even when dealing with such a well-known genus as Apios.— B. L. ROBINSON, *Gray Herbarium*.

A CONTRIBUTION TO THE KNOWLEDGE OF THE FLORA OF TUSCOLA COUNTY, MICHIGAN.[1]

DURING the summer of 1897, while engaged in field work for the Michigan Geological Survey, in that part of Tuscola county which lies adjacent to the eastern shore of Saginaw bay, the writer found what proved from the botanical standpoint an extremely interesting tract of country. This was a narrow, irregular strip of land somewhat back from the bay shore, known locally as the "prairie," which was rarely more than two or three miles in width, frequently much less, and at no very distant time had been a part of the bottom of the bay.

As the geological history of this tract has a clearly defined bearing upon the distribution of the plants which grow upon it, and as it is plainly set forth in easily read records, I will briefly trace it.

The bay off this shore is, and apparently always has been, very shallow. There are areas of the bottom also in which there are broad sand bars. These bars are often of considerable extent, but are still beneath the surface, and are only a few feet higher than the rest of the bottom. After a time one of these bars, in a part of the bay more exposed to the action of waves, is built up until its top is raised above

[1] Read before the Michigan Academy of Science, March 31, 1898.

the surface of the water, and the island thus formed being added to by the action of winds, waves and currents, soon builds itself inward at one end nearly or quite to the mainland, forming a spit, and shutting off more or less completely a shallow bay or lagoon, which may be of small or of large extent. After the barrier is raised in front, the inclosed body of water, sooner or later, is surely filled up, and becomes solid land. If the portion of the bay bottom cut off by the "spit" was already filled with sand reefs and bars, with deeper places between them, the process of filling is hastened, for the bars are rapidly added to under the protection of the outer barrier, until their tops are near enough to the surface of the water to get sufficient light to enable seeds of water-plants, which may germinate upon them, to make successful growth. Such plants, once established, become very important factors in hastening the deposit of sediment. The growth of plants undoubtedly is also fostered by the shelter which the spit gives, as in the quiet water behind it the sand and other sedimentary deposits are practically stationary, while in front of it there is constant shifting under wave and current action, so that plants are unable to gain a foothold, where conditions are otherwise favorable.

Such a spit-formed inlet, under ordinary conditions and with no fluctuations in the level of the bay, in the course of no very great interval of time would become partly filled with a series of islands, more or less sandy, and this phase would give place in due time to a marsh, in which would be strips of sandy or gravelly soil. In the meantime the spit would extend itself in breadth and length, and would form a new boundary for the waters of the bay, upon which the wind would heap sand and débris until a dune-line was formed.

Actually one can read this story over and over again in the region under consideration, its variations being practically limitless and its editions of all sizes.

There are easily found, also, evidences of periods of subsidence of the waters of the bay, of greater or less extent and duration. The past ten or twelve years have witnessed such a period, during which the water-level fell four feet, and even now, when the water is rising again, it is easy to see that the bay will never again occupy all the ground it did before its subsidence, for in bodies of water so shallow as Saginaw bay, a change of level of even a foot makes a very marked change in the shore-line, and competition for place is so keen among plants that every available inch of ground exposed by such a change

is soon occupied by them. At least some of this is never given back to the dominion of the waters.

With these facts in mind, let us look over the "prairie" region again, and consider its aspect. The whole section is, as nearly as possible, perfectly flat, the slope to the bay being only four feet to the mile, and treeless, except for thin and straggling lines of trees which are to be seen here and there. The bay is not visible, for there is a line of low tree-covered sand dunes which shuts it off from view, and which has an exaggerated importance seen across the flat expanse of the "prairie." At times this line of dunes looks almost like a line of hills when seen from a distance, yet by actual measurement the highest parts are hardly ten feet above the water level. Besides the lines of trees mentioned there are visible small groves and scattered groups of trees and shrubs, the "islands" in the "prairie." In short, the whole character of the view suggests that about the southern end of Lake Michigan, only here all the surface features are on a much smaller scale.

An inspection of the character of the soil shows three well-defined types distributed in the following manner: (1) sandy ridges, often continuous for considerable distances, varying from a few inches to three or four feet in height above the general level, and rarely more than a few rods in width; (2) broader, more or less extensive tracts of sandy loam; (3) black, vegetable mold which constitutes the greater part of the prairie soil.

The sandy strips are the tree-covered portions, the groves and islands, and, in the light of the history just discussed, they evidently represent dune and sand-spit lines of former days of bay occupation, when the sandy loam tracts were shallows and submerged bars; and the black mold represents the deeper places which have been filled in by the growth and decay of generations of plants under such conditions that their remains were preserved in part. The floras of these three classes of soil are quite distinct and are all interesting, but that of the sandy loam is by far the most peculiar, and is worthy more exhaustive study than the writer was able to give it.

Before discussing it, however, I wish to call attention, briefly, to the plants which characterize the other two classes of soil. The black soil is so largely under cultivation that I was unable to judge much of the higher portions, but in undrained and low places the vegetation, as would be expected, was distinctly limnetic, sedges (especially *Carex*

fusca, various species of Scirpus, and Eleocharis) and marsh-loving grasses predominating. The sandy ridges were covered with oaks, which with poplars and the species of plants which usually grow with them were to be expected from the character of the soil.

My interest was chiefly centered in the plants of the sandy loam tracts on which there were found growing in greatest profusion the following species, which here are found much to the north and in most cases east of their recorded range in the state, which is quoted from Beal and Wheeler's *Michigan Flora* (1892).

Cratægus Crus-galli L. Found on the border of a tract of sandy loam near the bay. Recorded from Lansing and southward.

Lythrum alatum Pursh, reported from near Detroit and from Kalamazoo, is here very abundant in damp places all over the district.

Ludwigia polycarpa Short & Peter, from near Flint and in St. Clair county, is here common in marshy places.

Silphium terebinthaceum Jacq. Ionia, Macomb county and southward, this plant was exceedingly abundant in places covering large tracts of the poorer soil and grows as far north as Sebewaing, Huron county.

Lacinaria spicata (L.) Kuntze grew with the Silphium and rightly earned its name of blazing star by making the country side brilliant in the middle of August. This plant has been found before as far north as Ionia county and from various other parts of the state to the southward and westward.

Cacalia tuberosa Nutt., reported from the southwestern part of the state, Kalamazoo, etc., was also common here.

Steironema quadriflorum (Sims) A. S. Hitch. was conspicuous and common. This plant has a southern range and seems not to be reported from so far north in the state.

The Asclepiadaceæ were generously represented by the following species:

Asclepias purpurascens L., reported from Ionia and Clinton counties and south.

Asclepias Sullivantii Englm. Not reported in the "Michigan Flora," but found by C. K. Dodge on an island in the St. Clair river, and having a range from Ohio to Kansas and Minnesota. This plant was very abundant on the prairie soil in Akron township, Tuscola county, and probably extends northward into adjacent townships in Huron county.

Acerates floridana (Lam.) A. S. Hitchc. Recorded from but one other station in Michigan, namely South Haven on the Lake Michigan

shore, where it was found by Professor L. H. Bailey. It was very abundant in the region under discussion, growing by roadsides, in uncultivated lands and even in some cases encroaching on cultivated ground and becoming a weed.

This list might be extended, but enough species have been enumerated to show that here is a northward and eastward extension of plants, of generally southwestern range, in an entirely unexpected part of the state and separated by considerable distances from the nearest other known stations.

The soil conditions are practically those of the prairie region of the southwestern corner of the state and of the adjacent region of Indiana and Illinois. Climatic conditions are also favorable for the existence of a colony of southern plants here, as the summer isotherms are the same as those of the lower end of Lake Michigan, and even the annual isotherms are but a few degrees lower than those of the southern border of Michigan, and a slightly later spring is practically all the difference in climatic condition of this locality as compared with those to the south.

Hence, since climate and soil are both favorable we have only to account for the introduction of these species into the region to explain the presence of the colony, and to do this satisfactorily, a more careful study of the region to the southwest will have to be made. One notable fact of the occurrence of this colony at this place is that it is entirely to the north of the Saginaw lobe of the great terminal moraine of the ice-sheet. The most northerly ridges of this moraine are at least a dozen miles to the south, and they extend northward into the middle of Huron county well to the east of this region, and while the course of the morainal ridge is such that plants might follow up the shore of Lake Huron and come around the bend in the moraine into the bay region, there are no traces of such a migration in Huron county, where the flora at critical points is entirely different. If the moraine is insurmountable to plants from the south, as has been supposed, then these species must have been carried across it by winds from the southwest, as is possible in case of some of them, since their seeds have a copious pappus or long coma.

Another possible agency of transportation is that of migrating animals, which might easily carry the seeds over the higher elevations, but this seems unlikely in this case, as birds are usually moving to the southward at the season when seeds of plants are most likely to be

carried, and the migrations of other animals in the state are too irregular and insignificant to be considered as a factor in the question.

On the other hand, it is also possible that the moraine is not too high to be passed by southern plants, and that stations have been established upon it during favorable periods which were occupied long enough to permit the plants to gain a foothold on the other side, and then the intermediate stations, because of a series of successive unfavorable years, have been destroyed.

In whatever way the matter is finally decided, the fact which is worthy of record at this time is that these plants occur at this point and that they thrive there and are thoroughly at home.

It is probable that similar tracts of land in Bay and Saginaw counties will yield the same species, thus extending their range still farther northward.— CHARLES A. DAVIS, *Alma College, Alma, Mich.*

OPEN LETTERS.

AERIAL TUBERS OF SOLANUM.

Editors Botanical Gazette: — W. R. Dodson, in the GAZETTE for January, refers to aerial tubers of *Solanum tuberosum*. It is well known that our varieties of potatoes in cultivation are obtained from selecting seedlings such as suit the cultivator best. From a thousand or two he may get only one, possibly two, three, or more, that he selects for further trial; the rest he abandons. Some eighteen years ago I grew 800 seedling potatoes from berries of several varieties. Among them were several which bore their tubers entirely on the stems above ground, and some produced tubers above and below also. One plant I remember in particular produced about 200 tubers, all at the surface of the ground and a little way above, none covered with the soil. These tubers were mostly the size of the ends of the thumb and fingers of a lady's hand. Of course, the plant was allowed to perish, as of no value. By selecting seedlings of this variable plant we can secure within certain limits anything we dare look for or expect.—W. J. BEAL, *Michigan Agricultural College.*

CURRENT LITERATURE.

MINOR NOTICES.

MESSRS. SEYMOUR AND EARLE[1] have issued a supplement to their series of economic fungi. It consists of forty packets of dried specimens, ten being species of Peronospora and Synchytrium marked *A*, and thirty of various Uredineæ marked *B*. The system of numbering is not explained, and, in fact, the printed matter accompanying the distribution consists only of a folded leaf bearing the title page and contents. Nearly a score of botanists have contributed to this first fascicle. The specimens are excellent, and the publication will doubtless meet with favor.—J. C. A.

NOTES FOR STUDENTS.

BULLETINS ON WEEDS are issued by the experiment stations from time to time and add greatly to a knowledge of the habits and distribution of this class of plants. A recent paper by H. Garman (Ky. no. 70, pp. 99–107, *pls. 2*) on "Woolly mullein (*Verbascum phlomoides*) in Kentucky" brings into notice a new roadside and riverside weed. At present it has invaded an area of about fifty square miles in the vicinity of Green river. It is a weed of waste ground rather than of cultivated fields.

"A first Ohio weed manual," by A. D. Selby (Ohio no. 83, pp. 247–400, *figs. 1–71*), forms a thick bulletin and gives information regarding 279 species of plants that should be subdued by the cultivator. Although the species are arranged in the usual systematic sequence, technical diagnoses are not employed. In their stead the striking features that would appeal to the untrained observer are clearly and simply set forth. Besides giving characters which assist in identifying the plant, the seeds are described so that they may be recognized when found in commercial seeds, and what is known regarding the noxious habits of the plants as well as practical methods of subduing them, form an important part of the presentation. The work closes with a tabulation of the distribution of roadside weeds in Ohio, from data furnished by 357 correspondents. The bulletin is an admirable and serviceable contribution to the literature of weeds.

[1] SEYMOUR, A. B., and EARLE, F. S.—Economic fungi supplement, including species of scientific, rather than of economic interest. Nos. *A* 1–10, *B* 1–30. Cambridge, Mass. 1898.

The "Fifth report of Kansas weeds," by A. S. Hitchcock and Geo. L. Clothier (Kans. no. 76, pp. 1–23, *pls. 12*), deals with the vegetative propagation of forty-eight perennials. A dozen plates with well-drawn figures illustrate the subterranean parts and habits of each sort of plant. Tests were made to determine the length of cuttings of roots or rhizomes that would throw out adventitious buds and become established as independent plants. The station is doing good work in issuing its series of weed studies.—J. C. A.

ELENCHUS FUNGORUM NOVORUM for the year 1897 appears in the April number of *Hedwigia*. It is prepared by G. Lindau and P. Sydow, and forms a third similarly published supplement to Saccardo's great *Sylloge Fungorum*. It is interesting to note that the enumeration of species published during 1895 reached the grand total of 1252, for 1896 of 1313, and for 1897 of 1476. This indicates increasing activity in the study of this class of plants. The enumeration does not include lichens and bacteria, but does include the myxomycetes and the myxobacteria.—J. C. A.

THE SPREAD of plant diseases was presented in a lecture before the Massachusetts Horticultural Society by Dr. Erwin F. Smith more than a year ago, but has only recently been printed and distributed. Much stress is laid upon the agency of insects, as they are especially prominent in the spread of pear blight, bacterial wilt of cucurbits, and bacterial brown rot of solanaceous plants, if not exclusively responsible for it. Slugs are known to distribute a number of diseases, including the bacterial brown rot of cabbage. Other methods of distribution are discussed, such as manure, soil, seeds, tubers, etc. A brief statement of preventive measures closes the lecture.—J. C. A.

RECENT BULLETINS from the experiment stations pertaining to vegetable pathology are as follows: "A bacterial disease of sweet corn," by F. C. Stewart (N. Y., no. 130, pp. 423–439, *pl. 4*), deals with a disease heretofore unrecognized. It is a bacterial disease attacking the plant at any stage of its growth, but more often at flowering time, causing the plant to wilt by clogging the fibrovascular bundles of the stem. The germ has been separated and inoculation experiments tried. It does not grow in field corn or pop corn. A review of the "cornstalk disease" of cattle, by A. T. Peters (Neb., no. 52, pp. 51–63), confirms the conclusion of some previous investigators that it is due to a germ entirely distinct from that causing the Burrill disease of corn, which in turn is distinct from the corn disease mentioned above. "A bacterial rot of cabbage and allied plants," by H. L. Russell (Wis., no. 65, pp. 1–39, *figs. 15*), has already received notice in this journal (25:67). "The olive knot," by F. T. Bioletti (Calif., no. 120, pp. 1–11, *pls. 3*, *figs. 2* in text), is an account of a disease which is more generally known under the name of tuberculosis of the olive. It was first seen in California in 1893, and is yet known in only one

locality. The disease is well described and illustrated. The germ causing it, *Bacillus Oleæ* Arch., was but little studied. Part of a bulletin (Ky., no. 72, pp. 9–23) is given to a report on the prevention of potato scab, by H. Garman. A detailed record of the work in 1896 and 1897 with use of corrosive sublimate shows very favorable results. In 1896 flowers of sulfur was also used, being placed in the drill with the seed tubers, but gave no benefit. "Blight and other plant diseases," by C. S. Crandall (Colo., no. 41, pp. 1–21), includes a good general account of pear blight, both historical and descriptive. Less extended descriptions are given of sun-scald and frost-cracks in fruit trees, leaf blight of strawberry, orange rust and anthracnose of raspberry and blackberry. A finely illustrated and well written bulletin on "Some important pear diseases," by B. M. Duggar (Cornell, no. 145, pp. 592–627, *figs. 15*) describes at length a leaf spot (*Septoria piricola* Desm.) that has heretofore received little attention. It is especially injurious to budded stock of two years or older, and is also prevalent in orchards, attacking only the foliage. Sprayings of Bordeaux mixture were found effective. It was studied microscopically, and also cultivated by the bacteriological method. A less extended account is given of leaf blight (*Entomosporium maculatum* Lev.), which has been confounded with the preceding, scab (*Fusicladium pirinum* Fckl.) and blight (*Bacillus amylovorus* Bur.), with original observations in each case and a brief bibliography. Notable results were obtained in imbedding and sectioning dense stromal tissues. "Rust and leopard spot, two dangerous diseases of asparagus," are described by W. G. Johnson (Md., no. 50, pp. 163–168, *figs. 2*), and their treatment indicated. The second-named disease is caused by an undetermined fungus, the first by *Puccinia Asparagi* DC. "Results with oat smut in 1897," by C. P. Close (N. Y., no. 131, pp. 441–154, also popular edition of 6 pages), show treatment with hot water, formalin, lysol, potassium sulfid, and Ceres powder, to have been effective in the order named, none of them being injurious to the seed. The same investigator has issued a bulletin on "Spraying in 1897 to prevent gooseberry mildew" (N. Y., no. 133, pp. 489–500, also popular edition of 6 pages), showing potassium sulfid to be a remedy far superior to Bordeaux mixture, lysol, or formalin. "Experiments and observations on some diseases of plants," by F. C. Stewart (N. Y., no. 138, pp. 625–644, also popular edition of 6 pages), demonstrates that the popular opinion that green manuring with rye to prevent potato scab, and the use of common salt on carnations to increase growth and prevent rust, have no rational basis. It is further shown that potato stem-blight (cause unknown) is not contagious, and that spraying cucumbers with Bordeaux mixture is especially serviceable against mildew (*Plasmopara Cubensis*). Interesting notes are given on the last named fungus, including a first record of its occurrence on *Cucumis Moschata* Duch. "Prevalent diseases of cucumbers, melons, and tomatoes," by A. D. Selby (Ohio, no. 89, pp.

99-122, 3 pl.), is an account of *Plasmopara Cubensis*, *Colletotrichum lagenarium*, and *Septoria Lycopersici* in Ohio, and efficient means to check them. Brief notes on corn diseases, by L. H. Pammel, and alfalfa leaf spot, by R. Combs (Iowa, no. 36, pp. 854–855, 858–859), are given as abstracts from the annual report of the Iowa Station for 1897.—J. C. A.

AN EXCELLENT illustrated paper on the "Fungous foes of the farmer" has been prepared by Dr. Byron D. Halsted for the Pennsylvania Department of Agriculture, and has been issued as bulletin no. 28 (1897). It is printed and distributed by the state at Harrisburg, Pa.

NEWS.

PROFESSOR L. M. UNDERWOOD, of Columbia University, sailed for Europe the first part of June.

PROFESSOR D. T. MACDOUGAL, of the University of Minnesota, will spend June, July and August in studying the vegetation of the arid regions of Arizona.

PROFESSOR STANLEY COULTER, of Purdue University, is spending his summer vacation abroad. He will devote some time to study in the laboratory of Professor Dr. Strasburger at Bonn.

THE IMPORTANT RESULTS of a vacation trip to Mexico in 1896, by which forty-five new species of *Uredineæ* and much other valuable mycologic material was secured, has decided Mr. E. W. D. Holway, of Decorah, Ia., to undertake another similar trip beyond our southern borders during the present summer.

LLOYD'S *Photogravures of American Fungi* give two views of *Polyporus Berkeleyi* Fr. for numbers 23 and 24. The specimen grew at the base of a large tree, and was two and a fourth feet across. The photographs and their reproductions are skillfully made, and bring out the characteristic features with great clearness.

THE ALABAMA Biological Survey has sent out a long and interesting list of plants for exchange, including not only flowering plants, but ferns, mosses, liverworts, lichens, and fungi. The specimens are well preserved, ample and authentic, and are largely from Alabama, with some from Colorado. The expedition during the season of 1898 to the mountainous region of southwestern Colorado (not southeastern, as erroneously stated in the February issue), will include several expert collectors, and all classes of plants will be gathered. This region is especially rich in species, and is also interesting for its great ecological diversity. Sets of specimens have already been ordered by the chief herbaria of this country, and by many foreign herbaria. Particular classes of plants, or forms illustrating ecological features, will be furnished at the same rates as for full sets. Inquiries and orders may be sent to C. F. Baker, Auburn, Ala.

GENERAL INDEX.

The most important classified entries will be found under Contributors, Diseases, Journals, Necrology, Personals, Reviews, and Societies. Names of new species are printed in **bold-face type**; synonyms in *Italics*.

A

A. A. A. S., Boston meeting 380
Abies balsamea, effect of transplanting 436
Acerates Floridana 456; Vail on 212
Achyranthes aspera obtusifolia 449
Actæa alba 229; spicata 229
Actinella *grandiflora* 294; Greene on 294
Æcidiospores, germination of 32
Æcidium Anchusae 28; Berberidis 28, 33; catharticae 28; Frangulae 28
Ægiphila odontophylla 157
Africa, new plants of 138
Agricultural Experiment Station, botanists at 218
Aglaozonia, Church on 378
Agropyron pseudorepens 385, 386, 389, 390, 394
Alaska, vegetation of 376
Alboff, N., biography 379
Albugo candidus 110
Alfalfa leaf spot 463
Algæ, west American thermal 89
Aligera, Suksdorf's key to 375
Allium odorum, polyembryony 295
Alloplectus **stenophyllus** 153; **ventricosus** 154
Alnus glutinosa 127
Alsine Jamesii 166; *stricta* 168
Alternaria Solani 296
Amarantus blitoides 258; chlorostachys 256, 259, 260
Ambrosia psilostachya 257, 258, 259, 260; trifida 259, Aphyllon on 57
American Society of Naturalists 143
Amphicarpæa, fruit production 117
Amorpha canescens 390, 391; *Caroliniana* 279; *cynostachya* 279; fruticosa 258, 279; glabra 279; herbacea 279; virgata 279, 359
Andropogon glomeratus 386; Hallii 391; provincialis 386, 389, 391; scoparius 385, 386, 390, 391; Virginicus 386
Anemone Caroliniana 389
Angiopteris, embryogeny of 309
Angiosperms, classification of 338
Anisophyllum 14
Antennaria campestris 389; Greene on 376
Antipodals, in Eichhornia 329; in Ranunculus 80
Anthoceros, embryogeny of 305
Anthocerotaceæ, Howe on 212
Apios Fortunei 451; macrantha 451; **Priceana** 451; tuberosa 451
Aphyllon Ludovicianum 57
Apple scald 297
Aquilegia Canadensis 239
Archegonium, Gayet on 68
Archesporium of Bignonia 111; of Ranunculus 74, 76, 78
Ardisia **pleurobotrya** 148
Arenaria Hookeri 393; *Lapponica* 168; Rossii 167; *stricta* 167, 168; uliginosa 167, 168
Argemone alba 392
Arisaema triphyllum 114
Aristida basiramea 391; oligantha 391; purpurea 385, 390, 391, 393
Artemisia cana 393; Canadensis 393; filifolia 393; frigida 393; tridentata 393
Arthur, J. C. 67, 134, 137, 216, 287, 293, 296, 376, 460, 461; and McDougal's "Living plants" 369; "Laboratory exercises in vegetable physiology" 293; "Movement of protoplasm in coenocytic hyphæ" 299
Arundinaria falcata 201
Asarum, Ashe on 294; Canadense 137; Shuttleworthii 294
Asclepias, pumila 390; purpurascens 456; Sullivantii 456; Ule on pollination 66
Ascomycetes, basidiomycetous stage in 107
Ashe, W. W., work of 294
Asparagus rust 462; spot 462
Aster multiflorus 257, 258, 259, 260, 390, 393; sericeus 390
Astragalus adsurgens 394; crassicarpus 389; mollissimus 394
Atkinson, G. F., personal 71; work of 107, 114
Atriplex confertifolia 373; expansa 257, 259, 260
Autran, Eugène 379

B

Babcock, S. M., work of 216
Bacillus amylovorum 462; Oleæ 462
Bacteria, in ripening cheese 216; Meyer on 213; new chromogenic 375
Bailey, L. H. 270, 283; personal 298; "Garden-making" 372; "Lessons with plants" 288
Bailey, W. W. 207; personal 380; "Botanical notebook" 63
Baker, C. F., personal 142
Baptisia bracteata 389
Barnes, C. R. 61, 132, 134, 135, 136, 137, 211, 288, 290, 292, 293, 369, 372; personal 218
Bartsia *pallida* 265
Bateman, Jas., death of 217
Beadle, C. D. 276, 357, 446
Beal, W. J. 459
Beans, lima 191
Bebb, M. S., herbarium 72
Beets, Kramer's bacterial disease 108
Berkeley, biography 300
Besleria **imbricans** 155; **macropoda** 155; Riedeliana 156; **robusta** 156
Best, G. N., work of 376
Bibliography 47
Bicknell, E. P., work of 137
Bidens connatus 58; tripartitus *faliax* 58
Bignonia, archesporium of 111
Bioletti, F. T., work of 461
Blepharoneuron, Nash on 376
Blepharoplasts 109
Bolander, H. N., death of 141
Bourreria formosa 150; **litoralis** 150
Bouteloua hirsuta 386, 391; oligostachya 385, 386, 390, 391
Bradlea 452
Brandegee, Mrs. K., work of 138
Brannon's "Grasses and forage plants of North Dakota" 134
Brassica sinapistrum 108
Brauneria pallida 359; **Tenneseensis** 359
Bray, W. L., work of 214
Britten, Jas., personal 299
Britten, Mrs. E. G., work of 137
Broom rape on ragweed 57
Brown University, botany at 207, 380.
Bryophytes, embryogeny 301; Gayet on archegonium of 68
Bulbilis dactyloides 385
Bulletin Torrey Botanical Club 217
Burmeistera **microphylla** 146; **tenuiflora** 147
Bunting, Martha, work of 117
Burt, E. A. 172; work of 107

C

Cabbage 204, 211; black rot 134; brown rot 67, 107
Cacalia tuberosa 456
Cactaceæ, Brandegee on 138; morphology, 114, 115
Cactus viviparus 391
Calamovilfa longifolia 391, 392
Calceolaria calycina 152; **sciadephora** 151; tomentosa 152
Caldwell, O. W. 66, 375
Calothrix gypsophila 95; thermalis 94
Campbell, D. H. 272; personal 217; work of 65, 374; on Naias and Zannichellia 65
Camphor tree 134
Canna, gum of 280
Capriola, Cynodon or 47; Dactylon 47
Carex acutina 271; *androgyna* 272; Douglasii *laxiflora* 271; fusca 455; **galbana** 271; **irrasa** 271; juncea 361; laxiculmis 450; luzulæfolia 272; **Madrensis** 270; *monticola* 272; **Oaxacana** 271; oblata **luzuliformis** 272; oligocarpa 360; *olivacea* 271, 272; Schiedeana 270; **Seatoniana** 270; spissa 270; stricta decora 271; triceps 271; **turgidula** 271; virescens 271
Carnation, Kinney on 296; rust 462
Caryophyllaceæ, North American 165
Cassia Chamæcrista 240
Castilleia *alpina* 264; breviflora 269; **cervina** 269; coccinea 239; **Cusickii** 267; **levisecta** 268; miniata *alpina* 264; **oreopola** 264; **pallescens** 266; pallida 265, 268, 269; pallida **camporum** 266; pallida **lutescens** 265; parviflora 265
Cavendishia **capitulata** 147; strobilifera 148
Ceanothus ovatus 391
Central America, undescribed plants from 145
Centrosomes, 109, 158
Cereals, Swedish researches on rusts of 26
Chamæsyce 18
Chamberlain, C. J. 64, 68, 124, 135, 139, 215, 295, 366
Chenopodium hybridum 259, 260
Chimaphila maculata 250; umbellata 250
Chlorophyll, Kny on function 70; Palladine on 296
Chrondrophora Douglasii 393; Howardii 393; nauseosa 393
Christ's "Farnkräuter der Erde" 283
Chroococcus varius 104
Chrysopsis villosa 391, 393
Church, A. H., work of 377

Clark's (A.H.) "Laboratory Manual" announcement 141; "Laboratory Manual in practical botany" 367
Clark's (Josephine E.) "Publications relating to poisonous and edible mushrooms" 292
Clements, F. E. (Pound and) 381; (Pound and) "Phytogeography of Nebraska" 370
Close, C. P., work of 462
Clothier, Geo. L. 53; work of 373; (Hitchcock and) work of 461
Cobb's "Letters on diseases of plants" 134
Codonanthe gracilis 154; **macradenia** 154
Collecting fungi 172
Colletotrichum lagenarium 463
Collomia *gracilis* 376; *nudicaulis* 376
Colorado, collecting expedition 142
Combs, R., work of 463; "Plants of Cienfuegos" 134
Compositae, Greene on 294, 376
Conferva major *f.* **ferruginea** 91; *f.* **gypsophila** 92
Conjugatae, West on 377
Conocephalus, embryogeny 304
Conopholis Americana 115
Contributors: Arthur, J. C. 67, 134, 137, 216, 287, 293, 296, 376, 460, 461; Bailey, L. H. 270, 283; Bailey, W. W. 207; Barnes, C. R. 61, 132, 134, 135, 136, 137, 211, 288, 290, 292, 293, 369, 372; Beadle, C. D. 276, 357, 446; Beal, W. J. 459; Burt, E. A. 172; Caldwell, O. W. 66, 375; Campbell, D. H. 272; Chamberlain, C. J. 64, 68, 124, 135, 139, 215, 295, 366; Clements, F. E. (Pound and) 381; Clothier, Geo. L. 53; Copeland, E. B. 427; Coulter, J. G., 215, 294, 295, 296, 373; Coulter, J. M. 62, 63, 73, 134, 135, 137, 138, 139, 209, 210, 212, 283, 292, 294, 367, 374, 375, 376; (and Rose) 53; Cowles, H. C. 69, 214, 216, 370; Cummings, Clara E. 284; Cushing, H. B. 353; Davis, B. M. 377; Davis, Chas. A. 453; Dodson, W. R. 59; Engler, A. 338; Eriksson, Jakob 26; Ferris, Carleton G. (Golden and) 39; Ganong, W. F. 143, 221; Golden, Katherine E. (and Ferris) 39; Greenman, J. M. 261; Guignard, L. 158; Harshberger, J. W. 362; Hill, E. J. 195; Holm, Theo 47, 246; Jordan, E. O. 213; Keffer, Chas. A. 131; Loeb, Jacques 54; Lawson, H. W. 68; Lutz, L. 280; Lyon, Florence M. 418; MacDougal, D. T. 282, 373; MacMillan, Conway 301; Merrell, W. D. 70; Millspaugh, C. F. 13; Nelson, Aven 196, 275; Noll, F. 1; Pound, R. (and Clements) 381; Robertson, C. 229; Robinson, B. L. 165, 437, 450; Rose, Jos. N. (Coulter and) 53; Rowlee, W. W. 199; Schaffner, J. H. 255, 395; Schneck, J. 57; Sharp, F. C. 287; Smith, E. F. 204; Smith, J. D. 145, 217; Smith, W. R. 65, 212, 324; Spalding, V. M. 65; Sturgis, W. C. 187, Tilden, Josephine E. 89; Toumey, J. W. 119; Warnstorf, C. 58
Convolvulaceæ, Hallier on 138
Copeland, E. B. 427
Coprinus micaceus 107
Coreopsis gladiata 448; **helianthoides** 448; longifolia 448
Cork tissue in roots of Rosaceæ 117
Corn, bacterial disease of sweet 461; diseases 463
Cornstalk disease of cattle 461
Cornus, 231; Canadensis, 231; *candidissima*, 233; florida, 232, 234; Mas 231; paniculata, 233, 234; sanguinea 232
Corylus Americana 127
Coulter, J. G. 215, 294, 295, 296, 373
Coulter, J. M. 62, 63, 73, 134, 135, 137, 138, 139, 209, 210, 212, 283, 292, 294, 367, 374, 375, 376; (and Rose) 53; personal 217
Coulter, Stanley, personal, 299, 464
Coville's "Report of the Botanist, 1897" 143
Cowles, H. C. 69, 214, 216, 370
Crataegus coccinea 446, 447; collina 357; Crusgalli 456; elliptica 447; flava 447; macracantha 446; microcarpa 360; punctata 357; rotundifolia 446; tomentosa 360; tomentosa **Chapmani** 360; tomentosa *microcarpa* 360
Cristatella Jamesii 392
Criticism, standpoint of 129
Cross's "Pollination of Eupatorium" 136
Cruciferæ, bacterial rot of 204, 211; brown rot 107; Smith on brown rot 67
Cryptanthe Fendleri 393
Cucumber diseases 462; mildew 462
Cucumis moschata 462
Cummings, Clara E. 284
Cupressus Lawsoniana 126
Curtis's "Text-book of general botany" 61
Cushing, H. B. 353
Cutleria multifida, Church on 377
Cyathium of Euphorbia 418
Cycadaceæ, Scott on 212
Cycloloma atriplicifolium 391
Cynodon or Capriola? 47

Cyperus Schweinitzii 391
Cytology, Eichhornia 330
Cyttarospermum 21

D

Dacryopsis *Ellisiana* 107
Datura Stramonium 259, 260
Davis, B. M. 377
Davis, Chas. A. 453
Delphinium, Greene on 294
Desmanthus brachylobus 258
Diatoms, of marine plankton 68
Dichothrix *gypsophila* 96
Dicotyledons, classification of 339
Diervilla rivularis 357
Diseases: Alfalfa leaf spot 463; apple scald 297; asparagus 462; beans, lima 191; beets, Kramer's bacterial disease 108; cabbage 204, 211, brown rot 67, 107; carnation, Kinney on 296, rust 462, conditions influencing dissemination of 187; corn, bacterial disease of sweet 461, diseases 463; cornstalk disease of cattle 461; cucumber diseases 462, mildew 462; gooseberry mildew 462; melon disease 462; oat smut 297, 462; olive knot 461; onion mildew 297; orange rust 462; pear blight 462, leaf blight 462, leaf spot 462, scab 462; potato blight 296, stem blight 462, scab 462, 463; raspberry anthracnose 462; rot, brown of Cruciferae, Smith on 67; Strasburger's leaf blight 462; tomato disease 462
Diseases, bulletins on 461; early work on 300; Halsted on 297
Disporum lanuginosum 358; maculatum 358
Dissemination of Ramalina 406
Distichlis maritima 256, 257, 259, 260; spicata 390
Distribution, geographic 382
Dodson, W. R. 59
Draba Caroliniana 389
Drymaria cordata 171
Duggar, B. M., work of 111, 462
Dumortiera trichocephala 273

E

Earle's (Seymour and) "Economic fungi" 460
Eastwood, Alice, work of 137
Eaton, A. A., work of 375
Eatonia obtusata 389, 391
Ecology 255, 381, 395, 404; professorship 141, 379; significance of orientation of egg 301
Ectocarpus siliculosus 378
Egg apparatus, Eichhornia 329; orientation of 301
Eggers, H., work of 212
Eichhornia crassipes 324
Elymus Canadensis 389; Virginicus 256, 258, 260
Embryos, of Cactaceæ 115; of Pontederia 333; of Ranunculus 84
Embryogeny 301; of Potamogeton 116; résumé 295; of Triticum 139
Embryo sac, Eichhornia 326; Euphorbia 420; Pontederia 332; Preda on 215; Ranunculus 78
Endosperm in Ranunculus 82
Engelmann Botanical Club 142
Engler, A. 338; and Prantl's "Natürliche Pflanzenfamilien" 298
Enslenia albida, propagation 374
Entomosporium maculatum 462
Enzymes, Waugh on 296
Episcia congesta 153; glabra 153; **longipetiolata** 152
Equisetum, embryogeny of 308
Eragrostis cuspidata 392; major 392; pectinacea 391; trichodes 391, 392
Erigeron Canadensis 258; Greene on 376
Eriksson, Jakob 26
Eriocarpum spinulosum 391
Eriogonum, annuum 391, 392; cernuum 393; flavum 393; Greene on 294; Small on 212
Euapios 450
Euphorbia adenoptera 21; Brasiliensis 16; campestris 25; corollata, life-history 418: dentata lasiocarpa 22; glyptosperma 258, 260; heterophylla graminifolia 23; hexagona 392; hypericifolia 14, 15, 17; Jaliscensis 23; Jaliscensis **Durangensis** 24; lasiocarpa 16, 17; lineata 14; marginata 258, 259, 260; montana 392; nutans 16; petaloidea 392: pilulifera procumbens 14; Preslii 14, 15, 16; prostrata 19; radians 24; serpens 18; serpens radicans 18; serpyllifolia 20; stictospora 19; subreniforme 21
Eurotia lanata 393
Evans's "Revision of North American species of Frullania" 135
Ewart, A. J., personal 379
Exchange, Alabama Biological Survey 404; Gintl's botanical 379

F

Fabroleskea, Best on 376
Fawcett's "Annual report" 373
Fernow, B. E., personal 71

Ferns of British West Indies 138; embryogeny 312
Ferris, Carleton G. (Golden and) 39
Fertilization, in Ranunculus 81; Mottier on 139
Festuca elatior 32
Fischer's "Cyanophyceen und Bakterien" 366
Flora, Alaska 376; Cushing's island, Maine 353; salt marsh of Kansas 255
Flowers, and insects 229; organogeny in Pontederia 332
Forcipella, Small on 376
Forester 300
Frankeniaceæ, Bray on 214
Fraxinus Americana 358; **Biltmoreana** 358; lanceolata 358; Pennsylvanica 358
Froelichia Floridana 391
Fruit, production in Amphicarpæa 117
Fungi, collecting and preparing 172; from coal mine 107; new 461
Fusicladium pirinum 462

G

Ganong, W. F. 143, 221; work of 114, 115
Garden and Forest, suspension of 72
Garden, Museum building for New York Bot. 71
Garman, H., work of 460, 462
Gaura parviflora 257, 258, 260
Gayet, work of 68
Gelsemium, internal phloem in 118
Geography, plant 381
Geranium Carolinianum 449; dissectum 449; molle 448
Germination of microspores of Ranunculus 76; of rusts 32; of seeds 114
Geum rivale 117; urbanum 117
Gilia iberidifolia 393; spicata 393
Ginkgo, embryogeny 319
Gintl, personal 379
Gloeocapsa violacea 103
Glycine *Apios* 452; frutescens 452
Glycyrrhiza lepidota 258
Goebel's "Organographie der Pflanzen" 290
Golden, Katherine E. (and Ferris) 39
Gooseberry mildew 462
Gramen *aculeatum* 49; *Canarium* 49; *dactyloides* 49; *dactylon* 47, 51; *legitimum* 50; *Mannae* 49, 50
Gramineæ and rusts 26
Graphium giganteum 107
Grasses, hosts of rusts 28; lodicules of 115; significance of lodicules 199
Greene, E. L., "Bibliographical difficulties in botany" 218; work of 137, 294, 376
Greenman, J. M. 261
Green's "Manual of botany" 62
Grindelia lanceolata 359; squarrosa 258
Groom's "Elements of botany" 282
Growth, effect of disinfectants on 296; injuries and 215
Guatemala, undescribed plants from 145
Guignard, L. 158
Gum of Canna 280
Gutierrezia Sarothra 393
Gymnosteris, Greene on 376

H

Hallier, work of 138
Halsted, B. D., "Fungous foes of farmer" 463; work of 297
Haplosiphon laminosus 97; major 97
Harper, R. A., personal 379; work of 110
Harshberger, J. W. 362; personal 141; work of 116
Helianthus, annuus 258, 259, 260, nutation of 395; divaricatus 244; Dowellianus 448; mollis 403; petiolaris 392; rigidus 403
Heliotropism of Helianthus 396
Herbarium, Alabama Biological Survey 464; Field Columbian Museum 299; Frost's collection of liverworts 299; L. N. Johnson for sale 71; M. S. Bebb 72; preparing fungi for 172; T. C. Porter 71
Heredity and hybridization 111
Hemerocallis fulva 335
Hepatica acutiloba 75, 80, 126
Heteranthera graminis 333
Hieracium aurantiacum 297
Hill, E. J., 195
Hitchcock, A. S., personal 218; work of 373; (and Clothier) work of 461
Holm, Theo 47, 246
Holwaya *tiliacea* 107
Holway, E. W. D., personal 464
Hooker, Joseph, personal 217
Hordeum jubatum 257, 258, 259, 260
Homalobus montanus 393
Hormiscia flaccida caldaria 91; subtilis thermarum 91; thermalis 94
Hosts for rust 28
Howe, M. A., "North American species of Porella" 136; work of 212
Humphrey, J. E., personal 141
Huth, work of 138
Hybridization and heredity 111
Hydrocotyle Bonariensis 450

Hydrocyanic acid gas, effects on plants and animals 113
Hydropterideæ, embryogeny 313
Hypericifoliae 14
Hymenochæte 107

I

Impatiens noli-tangere 69
India, completion Flora of British 217
Indiana Academy Science, botanical papers at 142
Insect pollination, Ule on 66; and flowers 229
Ipomoea leptophylla, root propagation 52
Ischæmon sylvestre 50; *vulgare* 49
Isoetes, embryogeny of 310; minima, Eaton on 375
Istvànffi, G., personal 141, 379
Iva ciliata 256, 257, 258, 259, 260

J

Jenman, G. S., work of 138
Johnson, D. S.. personal 298
Johnson, L. N., herbarium and library 71
Johnson, W. G. 462
Jones, L. R., work of 296
Jordan, E. O. 213
Journals: Bulletin Torrey Botanical Club 217; Forester 300; Garden and Forest, suspension of 72; Journal of Applied Microscopy 135, 217; Pharmaceutical Archives 142, 300, Review 142
Juglans cinerea 386; nigra 386
Juncus trifidus 278
Jungermanniaceæ 273, 274; embryogeny of 307
Juniperus Californicus Utahensis 196, 197; communis 199; communis Sibirica 199; **Knightii** 197, 198; occidentalis 196; occidentalis monosperma 196; Sabina 199; scopulorum 196, 199; Virginiana 196

K

Kansas Academy Science, botanical papers before 218
Kansas, salt marsh plants 255; weeds, Hitchcock and Clothier on 461
Kannenberg's "Kleinasiens Naturschätze" 283
Karyokinesis, Eichhornia 331
Kearney, T. H., work of 137
Keffer, Chas. A. 313
Kempe, F., personal 141, 379
Kentucky, new Apios from 450
Kinney, L. F., work of 296
Kirk, Thos. W., personal 379
Kny, L., work of 70
Kœleria cristata 385, 389, 390, 391, 393
Körnicke, F., personal 380; work of 139
Kraunhia 452
Kraus, G., personal 141
Kuhnisteria candida 390

L

Laboratory, Mexican botanical 362; supplies for 217
Laciniaria punctata 390; scariosa 390; spicata 456; squarrosa 390
Lathyrus ornatus 392
Lawson, H. W. 68
Leaves, effect of transplanting on size 427; of Pyrola aphylla 247
Lecanidion leptospermum 107
Leskea *Austini* 376
Lespedeza capitata 231; procumbens 230; reticulata 230; *Virginica* 230
Lilaea subulata, Campbell on 374
Lilaeopsis, Carolinensis 54; lineata 54; notes on 53; Schaffneriana 53
Limodorum abortivum 162
Lindau, G., work of 461
Linum rigidum 392
Lithospermum, Greene on 294
Lloyd's "Photogravures of American fungi" 141, 464
Lobelia cardinalis 239
Lodicules of grasses, significance of 115, 199
Loeb, Jacques 54
Lonicera 238; alpigena 239, 241; caprifolium 240; cœrulea 240; Iberica 241; Japonica 241; longiflora 239; nectar in non-twining and twining species 240; nigra 241; periclymenum 240; sempervirens 239, 241; Sullivantii 242; Tartarica 241; xylosteum 239, 240
Luchman, J. G., personal 298
Ludwigia polycarpa 456
Luina *Piperi* 376
Lupinus Plattensis 394
Lutz, L. 280
Lycopodium, embryogeny 314
Lyon, Florence M. 418
Lythrum alatum 456

M

MacDougal, D. T. 282, 373; personal 464; (Arthur and) "Living plants" 369; "Movements of plants" 134; "Province and problems of plant physiology" 298

Macfarlane, J. M., work of 106
MacMillan, Conway 301
Macoun's "Contributions to Canadian botany" 210; "Cryptogamic Flora of Ottawa" 298
Macroscepis **congestiflora** 149
Macrosporangia of Ranunculus 78
Macrospore of Ranunculus 78, 79
Maine, Wild flowers of Cushing's island 353
Malvastrum coccineum 393
Marchantia, embryogeny of 304
Marchantiaceæ 273, 274; embryogeny 305
Marsilea quadrifolia 125; embryogeny of 313
Mastigonema thermale 95
Mattirolo, O., personal 379
McClatchie, A. J., personal 298
Megaspores, Eichhornia 326; Euphorbia 420; Pontederia 332
Megasporangia, Euphorbia 420
Melon disease 462
Meriolix serrulata 392, 393
Merrell, W. D. 70
Mertensia, Greene on 294
Merulius 107
Mexico, botanical station in 362
Meyer, A., work of 213
Michigan, flora of 453
Microsporangia, Euphorbia 421; Ranunculus 74
Microspora amoena *f.* **thermalis** 92; **Weedii** 93
Microspore, Eichhornia 324; Euphorbia 422; Pontederia 333; Ranunculus 74
Microsteris, Greene on 376
Millspaugh, C. F. 13; "Contribution III to flora of Yucatan" 292
Minnesota Academy Science, botanical papers at 72
Moneses uniflora 250
Monoclea, dilatata 272; Forsteri 272; Gottschei 272; systematic position of 272
Monocotyledons, classification of 338
Morphology, experimental 114
Mottier, D. M., work of 139
Movements of Helianthus 396
Mueller, F. von, memorial 299
Muhlenbergia pungens 391, 392, 393
Mullein, woolly 460
Munroa squarrosa 392
Murray, G., work of 68
Mushrooms as food 218
Mycelium, from coal mine 107
Mycoderma Humuli 45
Mycorhiza in roots of Philesia 106
Mycotheca Italica 142
Myosurus, Greene on 294

N

Naias, Campbell on 65
Narcissus, Preda on 215
Nash, G. V., work of 376
Nature study, Purdue leaflet on 299
Necrology: Bolander, H. N. 141; Bateman, Jas. 217
Nelson, Aven 196, 275
Nemacladus rigidus 269
New England Botanical Club 299
New York Botanical Garden, Museum Building 71
Noll, F. 1; personal 380
Nomenclature 299, 437
Nuclei of embryo sac, Mottier on 139
Nuphar luteum 162
Nutation of sunflower 395
Nymphæa alba 162; leaf form 216

O

Oat smut 297, 462
Œnothera fruticosa 240
Œdogonium crenulato-costatum aureum 90
Œnothera biennis 258, 260
Ohio weeds, Selby on 461
Olive knot 461
Onion mildew 297
Ophioglossum, revision 137
Opuntia arborescens 121, 122, 123, 124; fulgida 119, 123; fulgida mammillata 119, 121; glaucophylla 221; humifusa 391; **spinosior** 119, 121, 123; spinosior **neomexicana** 119; tetracantha 121; tortispina 221; versicolor 119, 121, 124; vulgaris 114; vulgaris, polyembryony in 221; Whipplei 122, 123
Opuntias, tree, of United States 119
Orange rust 462
Oreocarya suffruticosa 393
Organogeny of Euphorbia 419
Organs, two new cell 110
Orophaca cæspitosa 393
Orthocarpus *pallescens* 266; *Parryi* 266; pilosus 267
Oryzopsis cuspidata 386, 391
Oscillatoria amphibia 102; geminata 102; princeps 101; tenuis 101
Osmunda cinnamomea 125
Osterhout, G. E., work of 294
Ovule, Euphorbia 420; integuments Eichhornia 330; Opuntia 222; Pontederia 332

P

Paleobotany, Scott's lectures 298
Palladine, W., work of 296

Pammel, L. H., personal 218; work of 463
Panicum crus-galli 49, 256, 259, 260; glabrum 50; longifolium 449; sanguinale 47, 48, 49, 50, 51; Scribnerianum 389, 391; virgatum 257, 258, 260, 389
Parasitism of Pyrola aphylla 247
Paryonychia Jamesii 393
Parthenogenesis, in Conjugatae 377; in Ectocarpus 378; Greene on 376
Paspalum setaceum 392
Pathology 187
Pear, blight 462; leaf blight 462; leaf spot 462; scab 462
Peck's "Annual report of the botanist, 1895" 137
Penhallow's "Review of Canadian botany" 379
Pentstemon albidus 393; caeruleus 393
Peridineæ of marine plankton 68
Pernettya ciliaris **alpina** 148
Personals, Atkinson, G. F. 71; Autran, Eugène 379; Bailey, L. H. 298; Bailey, W. W. 380; Baker, C. F. 142; Barnes, C. R. 218; Britten, Jas. 299; Campbell, D. H. 217; Coulter, J. M. 217; Coulter, Stanley 299, 464; Ewart, A. J. 379; Fernow, B. E. 71; Gintl 379; Harper, R. A. 379; Harshberger, J. W. 141; Hitchcock, A. S. 218; Holway, E. W. D. 464; Hooker, Joseph 217; Humphrey, J. E. 141; Istvànffi, G. 141, 379; Johnson, D. S. 298; Kempe, F. 141, 379; Kirk, Thos. W. 379; Körnicke, F. 380; Kraus, G. 141; Luchman, J. G. 298; MacDougal, D. T. 464; Mattirolo, O. 379; McClatchie, A. J. 298; Noll, F. 380; Pammel, L. H. 218; Phillippi, R. A. 298; Ramaley, F. 71; Saccardo, D. 142; Snow, Julia 217; Strasburger, E. 379; Underwood, L. M. 464; Wiesner, J. 298; Zacharias, E. 298, 379
Peters, A. T., work of 461
Pennington's "Study of Spirogyra" 136
Pfeffer's "Pflanzenphysiologie" 132, translation 141, 379
Phaca longifolia 392
Phanerogams, embryogeny 319
Pharmaceutical, Archives 142, 300; Review 142
Philadelphus grandiflorus *floribundus* 277; hirsutus 277; latifolius 277
Philesia, mycorhiza in roots 106
Philippi, R. A., personal 298
Phloem, internal 118
Phlox Douglasii 393; Hoodii 393
Phormidium laminosum 98, *f.* **Weedii** 99; luridum 101; purpurascens 101, rubrum 100; tenue 100
Phototropism of Helianthus 396
Physalis lanceolata 258
Physiology, present problems of 54
Phytophthora Phaseoli 191
Picradenia, Greene on 294
Picea alba, effect of transplanting 433; *Canadensis* 433; excelsa, effect of transplanting 435; *Mariana* 434; nigra, effect of transplanting 434; pungens, effect of transplanting 434
Pieters, A. J., work of 114
Pinus, Austriaca, effect of transplanting 433; Banksiana 126; Laricio 125; Strobus, effect of transplanting 433
Plagiobothrys, Greene on 294
Plankton, Murray on 68
Plantago Coronopus 51; Purshii 392
Plasmopara Cubensis 462, 463
Plectritis, Suksdorf's key to 375
Plum, Waugh on pollination of 296
Poa pratensis 32
Poinsettia 22
Polanisia trachysperma 392
Polemonium **bicolor** 262; humile pulchellum 263; Richardsonii 263; viscosum **pilosum** 263
Pollen, Eichhornia 324; Euphorbia 422; Pontederia 333; Ranunculus 74
Pollination 229; of plum 296; Ule on insect 66
Polyembryony, Hegelmaier on 295; in Opuntia 114, 221
Polygala alba 393
Polygonum aviculare 51; Hydropiper 256, 258, 259 260; Persicaria 256, 258, 259, 260; ramosissimum 256, 257, 258. 259, 260
Polymnia Canadensis radiata 278; **laevigata** 278
Polyporus annosus 107; Berkeleyi 464; versicolor 107
Pontederiaceæ, life history 324
Pontederia cordata 332
Populus alba 447; balsamifera candicans 447; sporangia 127
Porter, T. C., herbarium 72; "Pennsylvania German in the field of natural sciences" 142
Porter-Strasburger, et al. "Text-book of botany" 372
Potamogeton, embryology of 116; interruptus 195; Robbinsii 195
Potato, aerial tubers of 59, 459; blight 296; stem blight 462; scab 462
Potentilla arguta 392

Poulsenia, Eggers on 212
Pound, R. (and Clements) 381; and Clements's "Phytogeography of Nebraska" 370
Prairie, vegetation regions of 381
Preda, A., work of 215
Prenanthes *stricta* 376
Prizes 218
Propagation, in Conjugatae 377; in Ipomoea 52; Kansas weeds 373; of Pyrola 250; of rusts 31
Prosthecidiscus 149; **Guatemalensis** 150
Protococcus botryoides *f.* **caldarius** 94
Prunus Besseyi 391
Psacalium *strictum* 376
Psoralea argophylla 394; floribunda 390; lanceolata 391, 393
Pteridophytes, embryogeny 308
Pteris, embryogeny of 312
Ptilepida, Greene on 294
Ptiloria tenuifolia 393
Puccinia Asparagi 462; coronata 27, 28; coronifera 28, 32; dispersa 28; glumarum 28; graminis 27, 28; Phleipratensis 28; Poarum 32; rubigo-vera 27, 28; rubigo-vera simplex 27, 28; simplex 27, 28; straminis 27
Pyrola aphylla, morphology of 246; chlorantha 250; minor 251; picta 250; rotundifolia 251; secunda 250
Pyrus occidentalis 262; *sambucifolia* 262

Q

Quercus alba 404; chrysolepis 404; Douglasii 404; rubra 386.

R

Raineria, Greene on 376
Rain, mechanical effects on plants 69
Ramaley, F., personal 71
Ramalina reticulata 404
Ranunculaceæ, Huth on 138
Ranunculus abortivus 73, 79; life history 73; multifidus 73, 79, 80, 84; septentrionalis 73, 78, 79, 80, 84
Raspberry anthracnose 462
Rattan's "Exercises in botany" 65
Redfieldia flexuosa 392
Respiration, Palladine on 296
Reviews: Arthur and MacDougal's "Living plants" 369; Arthur's "Laboratory exercises in vegetable physiology" 293; Bailey's (L. H.) "Garden making" 372, "Lessons with plants" 288; Bailey's (W. W.) "Botanical notebook" 63; Brannon's "Grasses and forage plants of North Dakota" 134; Christ's "Farnkräuter der Erde" 283; Clark's (A. H.) "Laboratory manual in practical botany" 367; Clark's (J. E.) "Publications relating to poisonous and edible mushrooms" 292; Cobb's "Letters on diseases of plants" 134; Combs's "Plants of Cienfuegos" 134; Coville's "Report of the Botanist 1897" 143; Cross's "Pollination of Eupatorium" 136; Curtis's "Text-book of general botany" 61; Engler and Prantl's "Natürliche Pflanzenfamilien" 298; Evans's "Revision of North American species of Frullania" 135; Fawcett's "Annual report" 373; Fischer's "Cyanophyceen und Bakterien" 366; Goebel's "Organographie der Pflanzen" 290; Greene's "Bibliographical difficulties in botany" 218; Green's "Manual of botany 62; Groom's "Elements of of botany" 282; Halsted's "Fungous foes of farmer" 463; Howe's "North American species of Porella" 136; Kannenberg's "Kleinasiens Naturschätze" 283; Lloyd's "Photogravures of American fungi" 141, 464; MacDougal's "Movements of plants" 134, "Province and problems of plant physiology" 298; Macoun's "Contributions to Canadian botany" 210; Millspaugh's "Contribution III to the flora of Yucatan" 292; Peck's "Annual report of the botanist 1895" 137; Penhallow's "Review of Canadian botany" 379; Porter's "Pennsylvania German in the field of natural science" 142; Porter-Strasburger et al. "Text-book of botany" 372; Pfeffer's "Pflanzenphysiologie" 132; Pennington's "Study of Spirogyra" 136; Pound and Clements's "Phytogeography of Nebraska" 370; Rattan's "Exercises in botany" 65; Rothrock's "Annual report on forestry" 131; Russell's "Bacterial rot of cabbage and allied plants" 211; Schively's "Life history of Amphicarpæa" 136; Schneider's "Text-book of general lichenology" 284; Schrenck's "Trees of St. Louis as influenced by tornado" 294; Seymour and Earle's "Economic fungi" 460; Shimek's "Ferns of Nicaragua" 135; Smith's (E. F.), "Black rot of cabbage" 134; Strasburger's "Das Kleine botanische Practicum" 64; Sydow's "Sylloge fungorum: Index hospitum fungorum" 287; Taylor's "Student's handbook of

mushrooms" 293; Uline's "Monographie der Dioscoreaceen" 210; Wagner's "Grundprobleme der Naturwissenschaft" 287; Wiley's "Flowers that never fade" 293; Wilson's "Nature study" 209
Rhizoclonium hieroglyphicum **atro-brunneum** 93
Riccia, embryogeny of 302
Rimpach, A. work of 138
Rivularia hæmatites 96
Robertson, C. 229
Robinson, B. L. 165, 437, 450
Root, of Pyrola aphylla 249; propagation of Ipomœa 52
Roots, cork in rosaceous 117; Rimpach on shortening of 138
Rosa Arkansana 391; stellata, Wooton on 376
Rosaceæ, cork tissue in roots 117
Rose, Jos. N. (Coulter and) 53
Rot, bacterial (or brown or black), of cabbage 204, 211; brown, of cabbage 107; brown of Cruciferæ, Smith on 67
Rothrock's "Annual report on forestry" 131
Rowlee, W. W. 199; work of 115
Rudbeckia *biennis* 278; pinnatiloba 277; triloba *pinnatiloba* 277
Ruellia ciliosa 240
Rumex, Brittanica 256; Osterhout on 294; venosus 393
Russell, H. L., work of 216; "Bacterial rot of cabbage and allied plants" 211
Rust, Swedish researches on grain 26
Rydbergia, Greene on 294

S

Sabulina *stricta* 168
Saccardo, D. personal 142
Saccharomyces Fresenii 45; glutinis 39; rosaceus 39
Sachs, J. von, biography 1
Sagittaria, leaf form 216
Salix, nigra 259; sporangia 127
Sambucus Canadensis 146; **oreopola** 146
Sarcobatus vermiculatus 393
Schaffner, J. H. 255, 395
Schively, Adeline, work of 117; "Life history of Amphicarpæa" 136
Schizothrix calcicola 98
Schneck, J. 57
Schneider's "Text-book of general lichenology" 284
Schrenck's "Trees of St. Louis as influenced by tornado" 294
Scirpus campestris 256, 258, 260; lacustris 256, 260; pungens 256, 257, 258, 260
Scott, D. H. work of 212
Seedlings of Cactaceæ 115
Seeds, germination 114
Selaginella, apus 125; embryogeny of 314; Underwood on 316
Selby, A. D. work of 460, 462
Senecio præcox, water storage 116
Separates, for authors 71
Septoria Lycopersici 463; piricola 462
Seymour and Earle's "Economic fungi" 460
Sharp, F. C. 287
Shimek's "Ferns of Nicaragua" 135
Sieglingia purpurea 392
Silphium terebinthinaceum 456
Siphonychia *Rugelii* 376
Small, J. K. work of 137, 212, 376
Smith, E. F. 204; "Black rot of cabbage" 134; work of 67, 107, 108, 204, 211
Smith, J. D. 145, 217
Smith, W. R. 65, 212, 324
Snow, Julia, personal 217
Societies: A. A. A. S., Boston meeting 380; American Society of Naturalists 143; Engelmann Botanical Club 142; Indiana Academy Science, botanical papers at 142; Kansas Academy Science, botanical papers before 218; Minnesota Academy Science, botanical papers at 72; New England Botanical Club 299; Society for Vegetable Morphology and Physiology 71, 106, 144; Vermont Botanical Club, papers before 220
Society for Vegetable Morphology and Physiology 71, 106, 144
Solanum, rostratum 259, 260; tuberosum, aerial tubers of 59, 459
Solenophora **calycosa** 152
Solidago Canadensis 259; Missouriensis 390; rigida 390; rupestris 390; uliginosa 359
Spalding, V. M. 65
Spartina cynosuroides 256, 258, 260, 389
Species, new North American 91, 93, 94, 99, 103, 137, 138, 165, 261, 270, 275, 278, 358, 359, 376, 448, 451; new Central American 145
Spergularia borealis 170; salina 170
Spergula *stricta* 168
Sphaerocarpus, embroyogeny of 303
Sphagna, new species North American 137
Spiræa *arbuscula* 261; betulæfolia *rosea* 261; densiflora 261; lucida *rosea* 261; pyramidata 261

Spiesia Lamberti 294
Spirulina **caldaria** 103; major 100, 103
Sporangia, winter characters 124
Sporobolus cryptandrus 391; cuspidatus 391; heterolepis 257, 258, 259, 260; Texanus 257, 259, 260
Squaw-root, American 115
Stamens, Euphorbia 421
Stangeria, Lang on 213
Steironema quadriflorum 456
Stellaria calycantha 167; crispa 167; obtusa 167; **oxyphylla** 165; *stricta* 168; Washingtoniana 166
Stem of Pyrola aphylla 248
Stewart, F. C., work of 461, 462
Stipa comata 385, 391, 394; setigera 386; spartea 389, 391; viridula 386
Strasburger, E., "Das kleine botanische Practicum" 64; personal 379; "Textbook of botany" 372
Strawberry leaf blight 462
Stropharia 107
Sturgis, W. C. 187
Stylosanthes riparia 279
Suæda diffusa 256, 259, 260
Suksdorf, W. N., work of 375
Sunflower, nutation of 395
Swingle, W. T., work of 110, 111
Sydow, P., work of 461; "Sylloge fungorum: Index hospitum fungorum" 287
Symbiosis, rust mycoplasma 37
Symploca thermalis 98
Synechococcus aeruginosus 103
Synedrella nodiflora 449

T

Tabebuia obtusifolia 157; **sessilifolia** 156
Tapetum, Bignonia 111; Ranunculus 74
Targionieæ 274
Taxonomy 137, 212, 294, 338, 375
Taxus baccata Canadensis 126; baccata, effect of transplanting 436
Taylor's "Student's handbook of mushrooms" 293
Tecoma radicans 239
Teleutospores, germination of 34
Tetraneuris, Greene on 294
Thalictrum purpurascens 80
Theobroma **simiarum** 145
Thermopsis, **arenosa** 276; **divaricata** 275; montana 275; rhombifolia 275, 276; Rocky mountain species 275
Thompson, Caroline, work of 118
Tilden, Josephine E. 89
Tithymalus 25
Tomato disease 462
Toumey, J. W. 119
Tournefortia *Nilsoni* 151; **subspicata** 151
Townsend, C. O., work of 215
Tradescantia Virginica 392
Trillium recurvatum 126; Körnicke on embryogeny 139
Triticum repens 28, 31
Tsuga Canadensis, effect of transplanting 436
Tubers, aerial, of potato 59, 259
Tylosemium 451

U

Ule, work of 66
Uline's "Monographie der Dioscoreaceen" 210
Underwood, L. M., personal 464; work of 376
Uredineæ, Swedish research on 26
Uredo glumarum 33
Uredospores, germination of 32

V

Vail, Anna M., work of 212
Verbascum phlomoides 460
Verbena bipinnatifida 390; hastata 390; stricta 390
Vermont Botanical Club, papers before 220
Vernonia gigantea 390; **Allenii** 263
Vibrioid 110
Viburnum prunifolium 237; pubescens 236
Vilfa *tricholepis* 376
Viola, Greene on 294; hastata 449; pubescens 449; tenella 278; tripartita 449

W

Wächter, work of 216
Wagner's "Grundprobleme der Naturwissenschaft" 287
Ward, H. M., work of 375
Warnstorf, C. 58; work of 137
Waterplants, leaf form in 216
Water, storage and conduction in Senecio 116
Waugh, F. A., work of 296
Webber, H. J., work of 109
Weddelinia, Wächter on 216
Weeds, bulletins on 460; orange hawkweed 297; vegetative propagation 373

West, W. and G. S., work of 377
Wiegand, K. M., work of 116
Wiesner, Julius, personal 298; work of 69
Wiley's "Flowers that never fade" 293
Wilson's "Nature study" 209
Wilson, Lucy L. W., work of 115
Woods, A. F. 113
Wooton, E. O., work of 376
Wootonia, Greene on 376
Wounding, effect on nutation 401
Wyoming, junipers of 196

X

Xanthium strumarium 258, 259
X-rays, Atkinson's studies 71

Y

Yeasts, red 39
Yucca glauca 391

Z

Zacharias, E., personal 298, 379
Zannichellia, Campbell on 65